Popular Astronomy

Vol. LII, No. 10 **DECEMBER, 1944** **Whole No. 520**

A Sun-spot Synopsis

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The success of life insurance during the twentieth century has been chiefly due to the favorable mortality, which has been progressively lowered especially at the ages at which most of the insured lives are to be found. The worst flare-up of unfavorable mortality was that of the influenza epidemic of 1918. The possible causes of that disastrous incidence have been carefully studied by the Committee on Atmosphere and Man. Raymond Pearl had shown by the method of partial correlation that the influenza mortality was closely related to that from all causes and even closer to that from organic heart disease. Other investigators have indicated that influenza and heart disease might both be due to some common cause. The Committee repeated the experiment, using 22 factors separately. All except climate were eliminated. The elements of temperature, humidity, and storminess remained as more fundamental than any other causative factors.

In his book, "The Pulse of Progress" (1926) Dr. Ellsworth Huntington of Yale has shown some significant figures relating influenza mortality to temperature. The epidemic was progressively more severe in the cities where the temperature was higher, as is shown in Table A.

TABLE A

INFLUENZA EPIDEMIC (1918) AND TEMPERATURE

Cities (U.S.)	Mean Temperature for 30 Days before Outbreak and for 10 days at Crisis	Death Rate per 1,000 from Influenza and Pneumonia
6 coolest cities	54° F.	2.6
6 next coolest cities	57½	3.0
6 next coolest cities	61	3.5
6 next coolest cities	63	4.2
6 next coolest cities	65	5.0
6 next coolest cities	70	5.2

In referring to the work of the Committee, Dr. Huntington commented that even climate and weather might be eliminated from the factors influencing influenza mortality, if we had sufficient knowledge to justify substituting variations in solar energy. Many distinguished scientists have stated that all the weather on the earth can be traced back to solar radiation. Of all forms of that radiation, sun-spots are the most dramatic, and, in the opinion of many observers, the most potent. Hence it becomes of interest to set forth some of the facts and hypotheses which have been discovered in recent years in regard to the activity of

sun-spots. In doing this it is necessary to steer a careful course between Scylla and Charybdis, for we shall see that even the doctors (experts) do not always agree in their diagnosis of the conditions.

Certain Fundamental Sun-spot Data

Certain fundamental facts regarding sun-spots have been tabulated for many years. Of these the number of spots has been tabulated longest and is the index most often studied. The Germans, Wolf and Wolfer, were the pioneers in this part of the work, which has been done systematically since 1833, and by calculations based on meager data extended back to the beginning of the year 1749.* At present, Dr. W. Brunner of Zurich is the chief worker in this field, and his results are published monthly in the *United States Weather Review*. The procedure is not so simple as might at first appear. For the spots are usually clustered together into groups. Then clouds or fog or rain may make it impossible to see the sun at all on certain days from any given point on the earth's surface. The first of these difficulties is dealt with by defining the Relative Number in terms of ten times the number of groups plus the number of separate spots. Thus $N = K\ (10\,g + n)$ where K is 0.6 for Zurich and may range from 0.5 to 2.0. Sometimes observer A will call a cluster one group while observer B will call it two groups, and thus A might find N to be $10 + 5 = 15$ while B would call it $20 + 5 = 25$. For this reason and also on account of the clouds and other obstacles to a view of the sun, observations are taken from many parts of the earth. While Dr. Brunner's first numbers are provisional, they are later adjusted to give the final official sun-spot numbers. The monthly numbers are an average of the daily observations and the yearly numbers are an average of the monthly ones. Hence the yearly number is in reality an approximate average daily spot number. Usually the provisional yearly numbers do not differ markedly from the final numbers. The latter are published periodically in the *Bulletin of the American Meteorological Society* and also in similar literature in other countries.

Another item which is tabulated nowadays is the proportion of the surface of the sun which is covered by spots. This is referred to as the sun-spot area or the spotted area. Some scientists have thought it preferable to study the spotted area in determining cycles rather than the number of spots, but so far they have been in the minority. This is partly because the areas have not been recorded for so long a time as have the numbers of spots. The formula for tabulating the latter

*However from A. Wolfer's paper in the April, 1902, *U. S. Monthly Weather Review* it is noted that in 1818 and later all the monthly numbers were based on actual observations (although not necessarily at the same observatory). Futhermore in 1749-1818 five of every twelve monthly numbers on the average were also so derived, the others being partly observations and partly graphic interpolation.

makes some allowance for the areas where many spots are grouped together.

A third item of distinct moment is the position (latitude and longitude) on the sun where the spots appear. Curiously enough they have been observed to appear only within two bands across the sun, one north and the other south of the sun's equator. These bands extend as a rule only from 40° to 5° from the equator, and the vast majority of the spots are to be found between 30° and 10° of latitude. The maximum number of spots is usually at about 15° to 18° latitude. This peculiar band effect has given rise to the hypothesis that the sun-spots may be caused more by an electrical than by a gravitational or tidal influence. For Birkeland has found that when a globe is magnetized the vortices group themselves in bands parallel to the magnetic equator, and as the degree of magnetization by the foreign body increases the bands move toward the equator. The zones in which sun-spots occur on the sun are similar to the two zones of cyclonic storms on the earth—which also is a magnetized body—except that the former are in somewhat lower latitudes; namely, 10° to 30° instead of 30° to 60°. Although the solar magnetic field is stronger than that of the earth, it is weaker in proportion to the size of the sun. Hence it is not unreasonable that a powerful influence such as Jupiter would hold the sun-spots nearer to the sun's equator than occurs with the cyclonic storms on the earth in relation to the earth's equator. Furthermore in the United States and Canada the cyclonic storms begin in high latitudes, increase in strength and then migrate to lower latitudes. Similarly, in accordance with Spoerer's law, each sun-spot cycle begins with a few spots at about 30° on either side of the equator. As their activity increases, new spots break out nearer and nearer to the equator, until about 10° is reached, when the cycle gradually dies away.

For a period of one or two years a new cycle of sunspots is arising in high latitudes of the sun before the old cycle has finally died away in the lower part of the spotted zone. This same arrangement takes place simultaneously on both sides of the sun's equator. In the official sun-spot numbers both sets of spots are combined and thus it is often difficult to obtain agreement as to just when a minimum is reached. The increasing numbers of the new cycle tend to offset the diminishing numbers of the waning series. As there are often substantial variations from month to month, what may at the time seem like the bottom of the curve may later appear to be but a minor fluctuation, more than offset in the next month. It is customary, however, for the astronomers to reach an agreement on such matters, so that future calculations may be on a uniform basis. The year is divided into tenths for this purpose. For example, the last minimum was at 1933.8 and the last maximum at 1937.9. This decimal arrangement is for convenience in making subsequent mathematical calculations.

The sun-spots are not equally divided between the northern and

southern hemispheres of the sun. Prior to about 1850 they seem to have been most frequent in the northern hemisphere, and then for at least fifty years in the southern hemisphere.

Although such matters as these are not included in the official tabulations of sun-spot numbers, they form the subject of separate observations by a number of experts. Thus, for example, Dr. H. T. Stetson of the Massachusetts Institute of Technology has for some time been keeping a separate record of the old cycle and the new cycle of sun-spots. This would be of particular interest in his work, which deals primarily with the electrical and magnetic disturbances of the upper atmosphere as they are reflected in radio reception, since the polarity of the sun-spot magnetism changes as the spots pass through each minimum. In one such change they pass from positive to negative, and in the next from negative to positive. Thus for such work the point of minimum in the sun-spot cycle would seem to be of particular significance. Nothing could be more urgent than knowing whether the prevailing force is one of attraction or repulsion.

Similarly Dr. Charles G. Abbot, of the Smithsonian Institution at Washington, D. C., has been a leading American pioneer in the study of plans for harnessing the energy of the sun. He has instituted many procedures for recording the amount of solar radiation and its periodic fluctuations. This has led to attempts at forecasting temperatures and precipitation for months in advance at different cities of the United States. Since this country entered World War II, the details of weather forecasting have been shrouded in secrecy due to their increasing importance in the determination of military strategy.

Some Mathematical Features of Sun-spot Cycles

In 1927 the British statistician, Yule, made a number of attempts to derive a mathematical formula for reproducing the yearly sun-spot numbers covering the period 1749-1924. He tried half a dozen regression equations of the form

$$\mu_x = a\,\mu_{x-1} - b\,\mu_{x-2} + c$$

and others of similar character. Then he tried some modifications of sine curves in an endeavor to allow for the general wave-like form of the sun-spot cycle. He suggested that an exponential modification might be successful and indicated $y = A\,e^{-at}\,(1 - \cos\theta\,t)$ as a likely form. Several other writers had preceded him in the endeavor to represent the combined influence of Jupiter, Saturn, and other planets by superposing one wave-like curve upon another. In 1935 Max Waldmeier suggested that each successive spot-cycle from minimum to minimum could be represented by a particular curve of a general family of curves. In 1938 Dr. John Q. Stewart of Princeton produced the general exponential form, with four parameters,

$$R = F\,\theta^{a} \cdot e^{-b\theta} \qquad (1)$$

TABLE B

YEARLY SUN-SPOT NUMBERS—WOLF AND WOLFER—FOR YEARS AFTER MINIMUM

Cycle Number	Minimum Year	—0—	—1—	—2—	—3—	—4—	—5—	—6—	—7—	—8—	—9—	—10—	—11—	—12—	—13—
1	1755	9.6	10.2	32.4	47.6	54.0	62.9	85.9	61.2	45.1	36.4	20.9	...	...	...
2	1766	11.4	37.8	69.8	106.1	100.8	81.6	66.5	34.8	30.6	...	...	...	...	...
3	1775	7.0	19.8	92.5	154.4	125.9	84.8	68.1	38.5	22.8	...	...	...	...	...
4	1784	10.2	24.1	82.9	132.0	130.9	118.1	89.9	66.6	60.0	46.9	41.0	21.3	16.0	6.4
5	1798	4.1	6.8	14.5	34.0	45.0	43.1	47.5	42.2	28.1	10.1	8.1	2.5	...	...
6	1810	0.0	1.4	5.0	12.2	13.9	35.4	45.8	41.1	30.4	23.9	15.7	6.6	4.0	...
7	1823	1.8	8.5	16.6	36.3	49.7	62.5	67.0	71.0	47.8	27.5	...	...	...	...
8	1833	8.5	13.2	56.9	121.5	138.3	103.2	85.8	63.2	36.8	24.2	...	...	...	...
9	1843	10.7	15.0	40.1	61.5	98.5	124.3	95.9	66.5	64.5	54.2	39.0	20.6	6.7	...
10	1856	4.3	22.8	54.8	93.8	95.7	77.2	59.1	44.0	47.0	30.5	16.3	...	...	...
11	1867	7.3	37.3	73.9	139.1	111.2	101.7	66.3	44.7	17.1	11.3	12.3	...	...	...
12	1878	3.4	6.0	32.3	54.3	59.7	63.7	63.5	52.2	25.4	13.1	6.8	...	...	...
13	1889	6.3	7.1	35.6	73.0	84.9	78.0	64.0	41.8	26.2	26.7	12.1	9.5	...	...
14	1901	2.7	5.0	24.4	42.0	63.5	53.8	62.0	48.5	43.9	18.6	5.7	3.6	...	...
15	1913	1.4	9.6	47.4	57.1	103.9	80.6	63.6	38.7	24.7	14.7	...	...	...	...
16	1923	5.8	16.7	44.3	63.9	69.0	77.8	65.0	35.7	21.2	11.1	...	...	...	...
17	1933	5.7	8.7	36.1	77.1	114.4	109.5	88.7	67.8	47.5	30.6	16.3	...	...	...

For the six years 1749 through 1754 the spot numbers are, respectively, 80.9, 83.4, 47.7, 47.8, 30.7, 12.2.

TABLE C

EXCESS OF OBSERVED OVER COMPUTED (STEWART) SUN-SPOT NUMBERS FOR YEARS AFTER MINIMUM

Cycle Number	Minimum Year	—0—	—1—	—2—	—3—	—4—	—5—	—6—	—7—	—8—	—9—	—10—	—11—	—12—	—13—	No. of Signs +	No. of Signs —
1	1755	+ 9.4	+ 8.0	+15.7	+ 1.2	−20.8	−23.6	+ 6.5	− 0.7	+ 2.9	+10.3	+ 6.1	...	...	...	8	3
2	1766	+ 3.4	+11.8	−11.1	− 8.3	− 9.1	− 3.0	+10.1	+ 0.8	+11.6	...	...	...	...	...	5	4
3	1775	− 2.9	+ 6.2	+16.9	+ 7.6	−28.9	−27.8	+ 2.5	+ 6.0	+ 8.5	...	...	...	...	...	6	3
4	1784	+ 4.4	+ 8.7	+17.4	+15.6	− 8.5	−16.1	−22.7	−19.2	− 1.0	+ 5.7	+16.1	+ 4.7	+ 5.9	+ 0.4	9	5
5	1798	− 1.6	+ 1.0	− 3.7	− 1.5	− 2.1	− 5.4	+ 5.8	+10.8	+ 6.6	+ 3.5	+ 0.1	− 2.0	...	...	6	6
6	1810	− 2.4	+ 0.1	+ 3.6	+ 6.9	− 5.0	− 1.9	− 2.5	− 4.9	− 4.6	+ 1.5	+ 3.2	+ 0.4	+ 1.2	...	7	6
7	1823	+ 0.7	+ 6.1	+ 1.7	− 3.5	−13.2	− 9.7	+ 1.0	+19.6	+12.5	+ 5.5	...	...	...	...	7	3
8	1833	− 4.2	+ 6.0	+ 6.7	+ 3.0	−10.0	−27.4	− 7.7	+ 6.7	+ 5.8	+ 8.5	...	...	...	...	6	4
9	1843	+ 3.2	+10.6	+22.2	+ 2.2	− 8.1	− 6.2	−27.9	−31.6	− 3.5	+11.8	+14.6	+ 7.5	+ 0.1	...	8	5
10	1856	+ 0.4	+ 5.8	+ 1.9	+ 8.8	− 2.3	−13.4	−13.0	− 7.1	+13.0	+ 9.6	+ 4.0	...	...	...	7	4
11	1867	+ 0.3	+18.6	− 1.4	+ 8.9	−28.1	− 9.5	− 6.9	+ 2.8	− 4.6	+ 1.0	+ 7.7	...	...	...	6	5
12	1878	+ 1.4	+ 3.4	+20.2	− 2.0	−13.7	− 7.1	+ 6.8	+12.5	+ 0.1	− 1.9	− 1.6	...	...	...	6	5
13	1889	+ 1.8	+ 0.3	+ 3.9	+ 6.1	− 2.1	− 6.8	− 4.7	− 7.1	− 5.4	+ 7.7	+ 1.3	+ 3.7	...	...	7	5
14	1901	− 0.3	− 0.7	− 0.1	− 6.2	+ 1.5	− 8.7	+ 8.3	+ 7.3	+14.8	− 0.7	− 6.5	− 3.8	...	...	4	8
15	1913	− 2.9	+ 5.7	+21.5	−14.1	− 0.5	−15.9	− 4.5	− 1.0	+ 4.6	+ 5.5	...	...	...	...	4	6
16	1923	+ 1.9	+ 3.8	0.0	− 7.0	− 8.6	+ 9.8	+13.6	+ 0.4	− 1.2	− 2.4	...	...	...	...	5	4
17	1933	− 1.6	+ 2.6	+ 5.3	− 4.4	− 1.9	+ .5	+ 1.7	+ 6.8	+ 9.5	+ 8.6	+ 4.3	...	...	...	8	3
Number	+	10	16	12	9	1	2	9	10	11	12	9	4	3	1	109	
of Signs	—	7	1	4	8	16	15	8	7	6	3	2	2	..	.. ..	79	188

and applied it to each of the sixteen cycles since 1749 which had then been completed. For any given cycle, F, a, and b are constants and θ is the number of years elapsed since the start of the new outburst. This is a frequency curve of Pearson's Type III, and is easily dealt with statistically through the use of the gamma functions and the incomplete gamma functions.

In Table B are shown the yearly sun-spot numbers which are under consideration.

The six yearly values for the years 1749-1754 are appended to Table B as they do not form a complete cycle. However, since there are only four variables in formula (1), it would be feasible to derive from these observations computed numbers for the cycle which ended in 1755. The first seven cycles are separated in Table B from the subsequent cycles because they were not based so directly on observation as were the numbers for 1833 and later. How successful Dr. Stewart has been in his formulation of the sun-spot numbers may be seen from Table C and the synopsis of it which appears in Table D.

TABLE D

Cycle Number	Number of Years in Cycle	Total of Yearly Sun-spot Numbers	Sum of Absolute Value of Residuals (Table C)	Ratio % (4) ÷ (3)	Average Value of Residuals (4) ÷ (2)	Zurich Maximum Sun-spot Numbers
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	11	466	105.2	22.6	9.6	86.5
2	9	540	69.2	12.8	7.7	115.8
3	9	614	107.3	17.5	11.9	158.5
4	14	846	146.4	17.3	10.5	141.2
5	12	286	44.1	15.5	3.7	49.2
6	13	235	38.2	16.3	2.9	48.7
7	10	389	73.5	18.9	7.4	71.7
Sum	78	3,376	583.9	17.3	7.5	..
8	10	652	86.0	13.2	8.6	146.9
9	13	698	149.5	21.4	11.5	131.6
10	11	546	79.3	14.5	7.2	97.9
11	11	622	89.8	14.4	8.2	140.5
12	11	380	70.7	18.6	6.4	74.6
13	12	465	50.9	10.9	4.2	87.9
14	12	374	58.9	15.8	4.9	64.2
15	10	442	77.2	17.5	7.7	105.4
16	10	410	48.7	11.9	4.9	78.1
Sum	100	4,589	711.0	15.5	7.1	..
Totals	178	7,965	1,294.9	16.2	7.2	..
Uncompleted 17	11	602	47.2	7.8	4.3	115.0

It may be observed from the right-hand margin in Table C that the computed numbers have more often been lower than the observed numbers. Thus for the 189 numbers there are 109 which have the plus sign, one is zero, and 79 are of the minus sign. The discrepancy is markedly greater for the years prior to 1833 (48 plus and 30 minus) as contrasted with the more accurate Wolfer data of the later cycles (61 plus and 49 minus). This may indicate less accurate sun-spot numbers rather than any defect in Dr. Stewart's formula. From the bottom margin of the table it may be noted that the 4th and 5th years after minimum, namely those near the maximum, show computed values which are nearly always greater than the observed numbers. On the other hand, the years near the minimum of the cycles more often show an excess of the observed values.

From Table D it may be noted that for the entire sixteen completed cycles the discrepancy between observed and computed yearly numbers averages about seven sun-spot numbers or 16% of an observed value. Here again the first seven cycles combined make a poorer showing (17.3%) than the later, more accurate, observations (15.5%). At present writing (September, 1944) some spots have already appeared in initiation of cycle 18, and thus it becomes of interest to record data for cycle 17 which is now approaching its end, although as yet uncompleted. In the eleven years of this current cycle which have so far elapsed there have been more spots than in any other since cycle 11, which began shortly after the American Civil War. The fit of computed to observed values has been better than that of any prior cycle. The residuals in cycle 17 were only 7.8% of the total numbers and the average residual only 4.3 spot numbers. Incidentally, the computed numbers covering 1933 to 1944 were published by Dr. Stewart in May, 1939, and thus involved a forecast of six years in advance. The data for 1944 have not been recorded in the above tabulations since observed data are not yet available for comparison. The fact that the same formula (1) which was used to reproduce the data of the past gave even more accurate results when applied to the future, furnishes a significant confirmation of the whole procedure.

It may be thought that an average residual of 16% is far too high for fitting a computed curve to observed data. In his first paper Dr. Stewart seems to have had some such misgivings as to the success of his work. Then in his second paper he pointed out some of the reasons for the conclusion that a much closer fit was unlikely to be found. He attributes about 10% to "the randomness of the spot-producing process." In a subsequent paper he pointed out that his predicted *monthly* numbers agree with the observed ones about as well as the Zurich smoothed monthly numbers agree with the observed numbers. In fact it may be said that not only sun-spots but also sun-spot numbers (whether smoothed or unsmoothed) are "fearfully and wonderfully made."

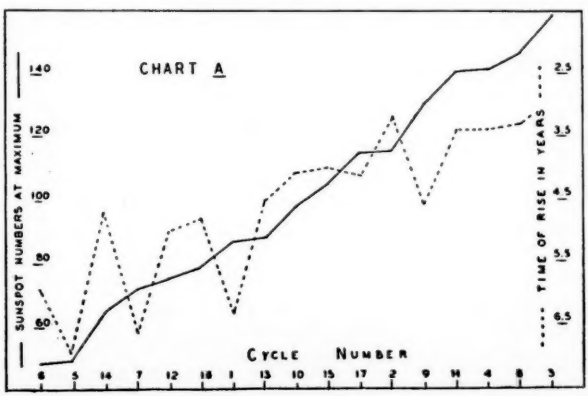
Several investigators have sensed some relationship between (a) the

years intervening between a minimum and its succeeding maximum (*i.e.*, the time of rise) and (b) the sun-spot numbers at the maximum. In Table E the seventeen cycles are arranged in order according to the maximum sun-spot numbers (Zurich), and, the relationship to the years of rise to a maximum being *inverse,* the tabulation of those years is shown inverted in Chart A, which shows Table E graphically. The general inverse relationship is evident, although irregular. For the twelve cycles with maximum less than 130 the one curve looks almost like a graded representation of the other curve. But for the five cycles with higher maxima the time of rise is relatively greater than the inverse relationship would suggest. Thus the two curves tend to fall away from each other after that point.

TABLE E

Cycle Number	Maximum Sun-spot Numbers (Zurich)	Number of Years Between Minimum and its Succeeding Maximum (Time of Rise)
6	48.7	5.8
5	49.2	6.9
14	64.2	4.7
7	71.7	6.6
12	74.6	5.0
16	78.1	4.8
1	86.5	6.3
13	87.9	4.5
10	97.9	4.1
15	105.4	4.0
17	115.0	4.1
2	115.8	3.2
9	131.6	4.6
11	140.5	3.4
4	141.2	3.4
8	146.9	3.3
3	158.5	2.9

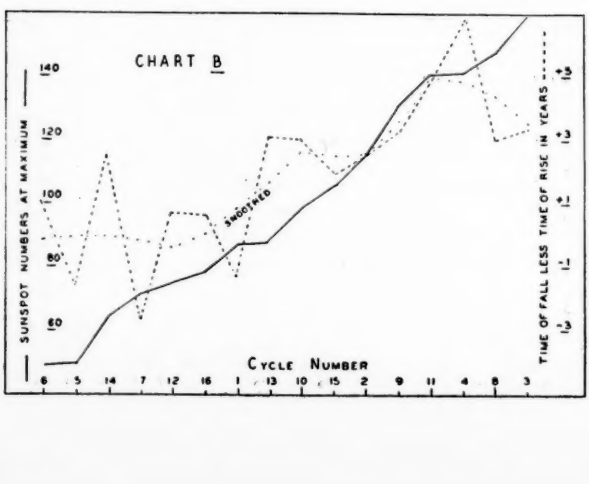
(See Chart A)



Another relationship of somewhat similar nature appears in Table F and graphically in Chart B. These show the time of fall (from maximum to next minimum) less the time of rise (from minimum to maximum), and indicate that this excess tends to vary *directly* with the sunspot numbers at the maximum. In order to remove minor irregularities a simple smoothing formula was employed on column (7) when it was arranged with cycles in numerical order, namely, $b = (a + b + c)/3$. Whereas the curve of maxima tends to be lower until 115 is reached, thereafter it ranges a little higher than the other curve.

TABLE F

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Cycle Number	Year of Minimum μ	Year of Maximum ν	Time of Rise $\nu - \mu$ (yrs.)	Time of Fall $\mu_1 - \nu_0$ (yrs.)	Cycle Number	Maximum Sunspot Numbers (Zurich)	Time of Fall less Time of Rise (years)	Col. 7 Graded [3]
1	1755.2	1761.5	6.3	5.0	6	48.7	+1.1	— .1
2	1766.5	1769.7	3.2	5.8	5	49.2	—1.5	+ .7
3	1775.5	1778.4	2.9	6.3	14	64.2	+2.5	— .5
4	1784.7	1788.1	3.4	10.2	7	71.7	—2.6	+ .2
5	1798.3	1805.2	6.9	5.4	12	74.6	+ .7	— .4
6	1810.6	1816.4	5.8	6.9	16	78.1	+ .6	0
7	1823.3	1829.9	6.6	4.0	1	86.5	—1.3	+ .8
8	1833.9	1837.2	3.3	6.3	13	87.9	+3.1	1.6
9	1843.5	1848.1	4.6	7.9	10	97.9	+3.0	2.7
10	1856.0	1860.1	4.1	7.1	15	105.4	2.0	2.5
11	1867.2	1870.6	3.4	8.3	2	115.8	2.6	2.6
12	1878.9	1883.9	5.0	5.7	9	131.6	3.3	3.6
13	1889.6	1894.1	4.5	7.6	11	140.5	4.9	5.0
14	1901.7	1906.4	4.7	7.2	4	141.2	6.8	4.9
15	1913.6	1917.6	4.0	6.0	8	146.9	3.0	4.4
16	1923.6	1928.4	4.8	5.4	3	158.5	3.4	3.6
17	1933.8	1937.9	...	...				
		Average	4.6	6.2		(See Chart B)		



This pivotal point (115) happens to be the maximum in cycle 17 now current, and for which we do not yet know the time of fall.

The facts brought out in Tables E and F and Charts A and B may be clarified by considering, respectively, the four extreme cases, namely those with (a) shortest rise, (b) longest rise, (c) shortest fall, and (d) longest fall. For convenience, these four cycles are summarized in Table G, from which the general nature of the curves will be apparent.

TABLE G

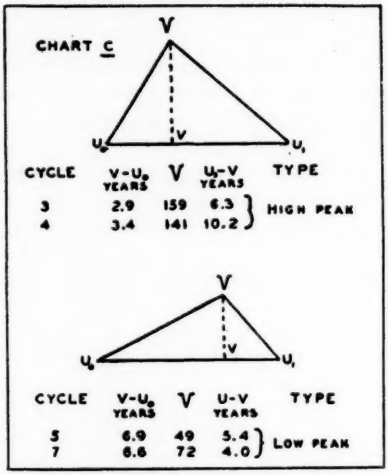
FOUR EXTREME CYCLES

Cycle Number	Maximum Sun-spot Numbers (Zurich)	Time of Rise (years)	Time of Fall (years)	Time of Fall less Time of Rise (4) — (3)	Character of Cycle
(1)	(2)	(3)	(4)	(5)	(6)
3	158.5	2.9	6.3	+3.4	Shortest Rise
5	49.2	6.9	5.4	—1.5	Longest Rise
7	71.7	6.6	4.0	—2.6	Shortest Fall
4	141.2	3.4	10.2	+6.8	Longest Fall

A comparison of column (3) with column (2) in Table G shows the result which was revealed in Chart A, namely an inverse relation between Time of Rise and Height of Maximum. Cycles 3 and 4 had high maxima and short periods of rise to maximum, while the reverse was true of cycles 5 and 7. Thus cycle 7 had a maximum only half that of cycle 4 and yet it took practically twice as long to reach its crest.

Comparing column (5) with column (2) of Table G confirms the relationship indicated in Chart B. The high maxima of cycles 3 and 4 were paralleled by large periods in column (5), while the reverse held for cycles 5 and 7. Thus when a sun-spot cycle has a high peak, it takes only a short time to reach that summit but a long time to reach its trough; while for the curves with low maxima the rate of rise is slow and the fall relatively precipitate. The following diagram (Chart C) illustrates these characteristics graphically, using a simple triangle for each type.

It is to be observed in passing that all four of the extreme forms of sun-spot cycles used in Table G and Chart C occurred prior to 1833, *i.e.*, in the period of less accurate figures. Yet this fact does not detract from the validity of the relationships set forth in Charts A and B. In fact, it will be of interest to apply these relationships to some of the cycles prior to 1755. The estimated years of minima and maxima have been calculated as far back as the invention of the telescope by Galileo. They appear, for example, in "Earth and Sun" (p. 256). With these figures as a basis, we can determine approximately the height of maximum upon the assumption that the relationships of Chart A apply in those years as well as in later periods. In Table H the cycles which precede cycle 1 (1755) have been numbered negatively from —1 (1745) to—13 (1610). From the columns of years of maximum and minimum



it is a simple procedure to tabulate the time of rise and also time of fall. Entering Chart A with the former yields the estimated maxima of column (6). Some confirmation of these values may be seen in the long-wave nature of their sequence. Thus proceeding backward from cycle 3 (159) we reach 84 in cycle —1, then ascend to 110 (—3), decrease to 45 (—5), then 130 (—6), decreasing to 30 (—8), increasing to 110 (—10), decreasing to 50 (—12) and then up again to 96 (—13). This feature is similar to the character of maxima in cycles 1 to 10 [col. (7) in Table D]. However, column (5) in Table H, which shows

TABLE H

SUN-SPOT CYCLES PRIOR TO 1755

Cycle Number	(1) Year of Minimum μ	(2) Year of Maximum ν	(3) Time of Rise $\nu - \mu$ (yrs.)	(4) Time of Fall $\mu_1 - \nu_0$ (yrs.)	(5) Time of Fall Less Time of Rise (yrs.)	(6) Estimated Height of Maximum
—13	1610.8	1615.5	4.7	3.5	— 1.2	96
—12	1619.0	1626.0	7.0	8.0	+ 1.0	50
—11	1634.0	1639.5	5.5	5.5	0	80
—10	1645.0	1649.0	4.0	6.0	+ 2.0	110
— 9	1655.0	1660.0	5.0	6.0	+ 1.0	90
— 8	1666.0	1675.0	9.0	4.5	— 4.5	30
— 7	1679.5	1685.0	6.0	4.5	— 1.5	70
— 6	1689.5	1693.0	3.5	5.0	+ 1.5	130
— 5	1698.0	1705.5	7.5	6.5	— 1.0	45
— 4	1712.0	1718.2	6.2	5.3	— 0.9	66
— 3	1723.5	1727.5	4.0	6.5	+ 2.5	110
— 2	1734.0	1738.7	4.7	6.3	+ 1.6	96
— 1	1745.0	1750.3	5.3	4.9	— 0.4	84
1	1755.2	1761.5	6.3	5.0	— 1.3	87
2	1766.5					116

the ungraded time of fall less time of rise, does *not* accord with Chart B. Indeed if we enter Chart B with the estimated height of maximum, and tabulate the figures which would be expected in column (5) they are quite different from the actual numbers in column (5).

The results of this test appear in Table I, in which the data are arranged in order by estimated height of maximum.

TABLE I

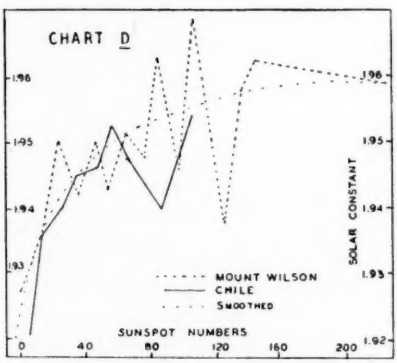
Cycle Number	Estimated Maximum Sun-spot Numbers (1)	Estimated Time of Fall less Time of Rise (years) (2)	Actual Time of Fall less Time of Rise (Table H) (3)	Residual (2) — (3) (years) (4)
— 8	30	—6.0	—4.5	—1.5
— 5	45	—4.5	—1.0	—3.5
—12	50	—4.0	+1.0	—5.0
— 4	66	—2.4	—0.9	—1.5
— 7	70	—2.0	—1.5	—0.5
—11	80	—1.0	0	—1.0
— 1	84	—0.6	—0.4	—0.2
— 9	90	0	+1.0	—1.0
—13	96	+0.6	—1.2	+1.8
— 2	96	+0.6	+1.6	—1.0
—10	110	+2.0	+2.0	0
— 3	110	+2.0	+2.5	—0.5
— 6	130	+4.0	+1.5	+2.5

The average absolute value of the residuals in column (4) is 1½ years, and it would not have helped any to smooth (a + b + c)/3 column (3), for in that case the average residual in column (4) would have been 2 years. It would be an interesting exercise to see whether certain modifications in the years shown in Table H could be arranged so as to reduce markedly the residuals in the last column of Table I.

While a sun-spot cycle is in progress an interesting question is as to when it will reach its minimum. From observation of the numbers for the cycles 1 to 16, it may be stated that the minimum tends to occur (a) one year after the sun-spot numbers are one-seventh of those at the maximum or (b) two-thirds of a year after they are one-tenth of the maximum.

Among the most devoted students of the sun, some place their special interest in the sun-spot numbers and others in the amount of solar radiation. In "World Weather" Clayton has presented a graph showing the relationship between these two indexes of solar activity. In Chart D the figures are indicated for Mount Wilson Observatory (1905-1920) and those of Chile (1918-1924). As there were more than 2,000 observations the smoothed curve shows a very clear relationship. The sun's heat radiated to the earth tends to increase with an increase in the number of sun-spots. It should be noted, however, that in a later paper (*Smithsonian Institution, Annals of Astrophysical Observatory,* vol. 6, p. 196; 1942) Dr. Abbot found no such relationship for the data

of 1920-1939. Further research on this matter must await the collection of additional material; for with a longer period under observation some differentiations could be made which might bring out relationships necessarily obscured by cruder tabulations. Dr. Stetson has stated (personal letter), "There is every evidence from ionospheric investigations that the output of the solar radiation, especially in the extreme ultra-violet, is 100 to 150% greater at sun-spot maximum than at sun-spot minimum. It would indeed be surprising if one did not detect some of this in the values of the solar constant, unless some exactly compensating absorption is encountered in the atmosphere that escapes the method employed in reducing the observed values to the values of solar radiation outside the atmosphere." Clayton points out that "evidence that the sun's radiation varies with the sun-spot period is found in the fact that the polar caps of Mars when turned toward the sun lessen in size when the spots are many and *vice versa*. Variations in the amount of light reflected by Jupiter have also been found to vary with the sun-spot period."



In "Earth and Sun" Huntington makes an interesting point in reference to the causation of sun-spots. He says, "The planets do *not* supply the energy shown in sun-spots and other movements of the sun's atmosphere. The energy derived from them may be no more than that of pressing a button, which starts an explosion. When a little eddy is once started the slight movement so generated may be reinforced by stresses due to the rapid cooling of the sun's outer layer, or to the sun's varying rate of rotation at different latitudes."

To the student of solar-terrestrial relationships there are many pitfalls and one must avoid too hasty generalizations. The fact that the polarity of the sun-spots changes at every minimum may explain many apparent contradictions. Clayton has shown that certain relationships to temperature, pressure, and the precipitation are reversed in some parts of the world as contrasted with other areas. Thus while a tropical

river like the Nile shows a maximum height near sun-spot maxima the reverse has been found for rivers in temperate regions such as the Parana river in the Argentine area. In recent years observations have been made of the numbers of sun-spots in the central zone of the sun and their curve differs from that of the official over-all sun-spot numbers. Thus Garcia-Mata found a huge maximum variation at the central zone from October to December, 1929, while the official maximum of all zones combined was in May, 1928; namely, seventeen months earlier. In the years to come there will doubtless be many articles written about the sun's influence on the earth. The constructive work will be of three types:—(1) The painstaking and patient accumulation of facts in many parts of the earth and at many seasons and years; (2) The tabulation of relationships among those facts, an estimation of their value of statistical methods, and the tentative establishment of laws regulating them; (3) The setting forth of hypotheses, which enable one to temporarily view the facts from a new and simpler aspect. The present paper is chiefly a review of some of the major work which has been done under the second of these headings.

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The Absolute Dimensions of the Stars

By SERGEI GAPOSCHKIN

Introduction. The fourth decade of this century is especially noted for the growth of the knowledge about the sizes, masses, and other associated characteristics (the absolute dimensions) of the stars. Therefore a synopsis of our knowledge of the absolute dimensions seems to be fitting. There is another reason for such a general summary of the absolute dimensions as it is my opinion that after this war we will probably have a new and different approach to the absolute dimensions, in which our present conceptions about the stars may probably have another meaning. I have, therefore, accumulated the absolute dimensions of stars, clusters, extragalactic nebulae, and variable stars in one table.

TABLE I

THE ABSOLUTE DIMENSIONS

Object	Galactic Conc.	M_{bol}	M_{vis}	m	μ	N	% of all	% of space
A, main sequ.	large	— 0.2	0.2	10	3.4	130,000	25	10^{-3}
A, emission	very large	— 7.8	— 7.5	6	38	50	10^{-5}	10^{-1}
A, subdwarfs	?	5.0	5.0	9	1	7	10^{-6}	10^{-6}
A, supergiants	very large	— 5.5	— 5.1	6	15	68	10^{-5}	10^{-2}
B, main sequ.	very large	— 5.0	— 3.5	10	20	12,000	2	10^{-1}
B, emission	7	— 6.8	— 5.3	8.1	30	350	10^{-4}	10^{-1}
B, supergiants	7	— 7.3	— 5.8	5.5	30	46	10^{-5}	10^{-2}
F, main sequ.	medium	2.1	2.1	10	2	50,000	10	10^{-4}
F, emission	?	— 7.5	— 7.5	5	?	2	..	10^{-2}
F, supergiants	very large	— 4.4	— 4.4	5	30	41	10^{-5}	10^{-3}
G, main sequ.	none	4.1	4.1	10	1.2	130,000	25	10^{-6}
G, subgiants	small	2.0	2.0	10	2.2	>10	..	10^{-5}
G, giants	large	— 0.4	— 0.4	10	4.0	800	10^{-3}	10^{-3}
G, supergiants	very large	— 3.6	— 3.6	5	10	56	10^{-5}	10^{-3}
K, main sequ.	none	6.5	6.0	10	0.7	200,000	33	10^{-6}
K, subgiants	small	2.8	3.3	10	1.6	>10	..	10^{-6}
K, giants	large	— 0.3	0.2	7	4	1,000	10^{-3}	10^{-5}
K, supergiants	very large	— 3.5	— 3.0	5	16	35	10^{-5}	10^{-5}
M, main sequ.	none	7.6	8.6	10	0.4	>50	10^{-5}	10^{-5}
M, subgiants	small	5	6	10	1	4	..	10^{-7}
M, emission	small	6.8	7.5	11	0.6	8	..	10^{-7}
M, giants	medium?	— 1.1	— 0.1	8	10	4,000	10^{-3}	10^{-7}
M, supergiants	very large	— 7.0	— 6.0	7	40	18	..	10^{-1}
N, emission	large	— 6.9	— 4.3	8	30	17	..	10^{-2}
N, supergiants	large	— 4.4	— 1.8	8	15	170	10^{-4}	10^{-3}
O, main sequ.	5	— 7.0	— 5.1	7.5	30	90	10^{-4}	10^{-2}
P Cygni stars	large	(— 8)	— 4.9	8	]30?	30	10^{-5}	10^{-1}
Plan. Nebulae	11	(— 4)	0.2	12.0	..	140	10^{-3}	10^{-3}
	...	?	2.0	13.8	..	140	10^{-3}	10^{-3}
R, giants		— 3.5	— 0.8	7	10	37	10^{-5}	10^{-4}
S, giants	20	(— 4.)	— 1.8	8	15	36	10^{-5}	10^{-3}
SUN	...	4.7	4.7	—26.7	$1=2\cdot10^{33}$ gm.	1	..	..
White Dwarfs	none	12.2	12.6	13.3	1	40	10^{-5}	10^{-3}
Wolf-Rayet stars	6	— 3.7	— 2.9	9.6	10.2	73	10^{-4}	10^{-2}

ORGANIZATIONS

Bright Nebulae	large	....	....	>3	(30)	>50	..	..
Dark Nebulae	large	....	....	..	(30)	>30	..	..
Extragalactic Nebulae	none	—15.1	—15.1	(17.)	10^{10}	10^4	..	..
GALAXY	...	—19.2	—19.2	..	10^{11}	1	..	1
Globular Clus.	large	— 7.2	— 7.2	8.0	10^6	94	..	0.5
Open Clusters	medium	— 1.0	— 1.0	10.5	10^3	334	..	10^{-2}

VARIABLE STARS

Algol and β Lyrae Stars	medium	1.0	1.2	11.	2.5	967	10^{-3}	10^{-3}
W UMa type	none	4.5	4.5	12.0	1.2	85	10^{-4}	10^{-5}
RR Lyrae	none	— 0.3	— 0.2	12.9	(2.5)	841	10^{-3}	10^{-1}
Cepheids ([10^4)	5.4	— 2.5	— 1.6	10.2	(8.0)	225	10^{-4}	10^{-3}
Cepheids (]10^4)	(5.4)	— 4.0	— 2.6	10.8	(14)	122	10^{-4}	10^{-1}
Long Period	27	— 4.0	— 1.5	9.7	(12)	290	10^{-4}	10^{-3}
Semiregular	22	— 3.3	— 1.8	(9.)	(11)	170	10^{-4}	10^{-3}
Novae	9	4.3	4.3	19.0	1?	90	10^{-5}	10^{-2}
Novae	...	— 7.9	— 7.9	..	..	...	..	..
Supernovae	...	(—14.5)	—14.5	..	..	40	..	..
U Geminorum	19	(5.)	(5.)	15.5	1?	36	10^{-5}	10^{-6}

TABLE I (CONTINUED)

THE ABSOLUTE DIMENSIONS (CONTINUED)

Object	R	Sp	C.I.	T_e	T_e†	ξ^*	$X_\odot$	V
A, main sequ.	2.3	A0	—0.14	10600	31	0.45	0.43	10.9
A, emission	135.	A2	(0.0)	lower?	(15)	0.6	0.6	..
A, subdwarfs	0.27	A4	..	higher?	70	0.3	0.4	..
A, supergiants	30?	A1	..	lower?	10	0.6	0.6	..
B, main sequ.	6.4	B1	—0.35	21000	65	0.5	0.5	19.4
B, emission	25.0	B2	—0.2?	lower?	30	0.6	0.6	..
B, supergiants	(25.0)	B2.5	..	...	..	..	..	..
F, main sequ.	2.0	F0	0.20	7400	30	0.45	0.45	14.4
F, emission	230.	F5	0.50	lower	3.2	0.3	0.6	..
F, supergiants	>50.	F	0.5	...	3.2?	..	..	..
G, main sequ.	0.9	G0	0.56	5750	27	0.45	0.4	15.0
G, subgiants	4.0	G1	0.7	5550	11	0.3	0.5	..
G, giants	10.	G0	0.83	5350	8.5	0.45	0.45	..
G, supergiants	50.	G0	1.14	5000?	4.2	0.3	0.6	..
K, main sequ.	0.8	K0	0.90	4500	19.	0.45	0.45	17?
K, subgiants	6.	K0	1.0	4100	8.	0.4	0.5	..
K, giants	60.	K0	1.12	3700	3.	0.3	0.5	17?
K, supergiants	230.	K0	1.58	3000	2.5	0.3	0.6	..
M, main sequ.	0.65	M1	1.47	3200	13.	0.4	0.4	..
M, subgiants	5.0	(M3)	1.5	3000	5.?	..	..	..
M, emission	0.7	M2	1.5	3100	18.	0.4	0.4	..
M, giants	130.	M0	1.88	3000?	1.5	0.3	0.6	17.1
M, supergiants	400.	M1	2.15	2800	(1.3)	0.3	0.7	..
N, emission	1600.	N3	(4.0)	1200	0.4	0.3	0.6	..
N, supergiants	600.	N3	(4.0)	1800	0.6	0.3	0.5	..
O, main sequ.	14.	O9	—0.2	27000	48.	0.6	0.6	25.5
P Cygni stars	25.	B1	0.2	(27000)	..	..	..	..
Plan. Nebulae	0.4	W6	..	90000	..	..	..	30.0
	10^5	...	..	...	..	..	..	30.0
R, giants	100.	R8	2.5	1500	1.5	0.4	0.5	18.5
S, giants	400.	S3	2.0	1240	0.8	0.3	0.6	..
SUN	$6,95 \cdot 10^5$ km.	G1	0.53	5713	21.	0.41	0.37	20
White Dwarfs	0.01	A	..	10000?	10^{-4}	..	..	..
Wolf-Rayet stars	5.9	W7	..	20000	36	0.4	0.6	34
ORGANIZATIONS								
Bright Nebulae	10^8	...	..	...	..	..	..	20
Dark Nebulae	10^8	...	..	...	..	..	..	15
Extragalactic Nebulae	10^{11}	G1	0.6	5800	..	..	..	..
GALAXY	$5 \cdot 10^{11}$	(F5)	..	...	..	..	..	275
Globular Clus.	10^6	G3	0.7	...	..	..	..	275
Open Clusters	10^8	B-K	..	...	..	..	..	15
VARIABLE STARS								
Algol and β Lyrae Stars	2.1	(A4)	0.0	8700	25	0.4	0.4	10?
W UMa type	0.9	G0	0.6	5750	20	0.4	0.4	..
RR Lyrae	4.0	A5	0.0	8500	13	0.5	0.5	150
Cepheids ($<10^d$)	30.	F9	0.5	5700	5	0.51	0.5	29
Cepheids ($>10^d$)	100.	G7	0.9	4600	3	0.48	0.5	29
Long Period	250.	M4-N3	..	2600	1.5	0.3	0.6	118-32
Semiregular	270.	M-N	..	2500	1.3	0.3	0.6	18?
Novae	0.7?	A?	..	?	?	?	?	..
Novae	200.	...	..	...	..	..	..	..
Supernovae	...	...	..	...	..	..	..	..
U Geminorum	0.7?	A-G	..	...	..	..	..	..

†Expressed in millions.

The Absolute Dimensions. The most commonly used terminology and notation have been adopted in this work, and it is hoped that about 700 entries in the table cover our inventory of information. Originally I planned to give detailed reference to each entry in the table together with the computations and selection of some individuals of each group. I am now giving only the table and the whole literature used by me in this work. For each source I have given the essential part which for my purpose was of interest; the designation often does not coincide with the name of the paper given by the authors themselves. The meaning of the columns is as follows:

Column 1. Name of object.
Column 2. The galactic concentration in respect to the galactic plane.
Column 3. The bolometric absolute magnitude (M_{bol}).
Column 4. The visual absolute magnitude (M_{vis}).
Column 5. The mean apparent magnitude for the stars observed (m).
Column 6. The mass of the group, referring to the given spectrum and radius, (μ), expressed in units of the sun.
Column 7. The observed number of the objects (N).
Column 8. The percentage of the objects in respect to the total observed stars (% of all).
Column 9. The percentage of space penetrated by the class (% of space).
Column 10. The radius (R), expressed in units of the sun.
Column 11. The spectral class to which the radius, mass, color indices, the effective and central temperature are given (Sp).
Column 12. The color indices (C.I.), on the international scale.
Column 13. The effective temperature (T_e), for the radius given before.
Column 14. The central temperature (T_c), for point source model.
Column 15. The central condensation (ξ^*).
Column 16. The hydrogen content (X_0).
Column 17. The velocity of the group in space (V).

The values of M, μ, R, T_e, and Sp constitute our chief interest and they are made consistent with each other within the table. I have computed the volume of the Galaxy to be 10^{12} cubic parsecs.

The degree of accuracy of the numbers given in the table naturally varies from item to item. A numerical error would be costly in effort but it will scarcely be of use for many data of the table are not accurate and represent only estimations expressing our opinion. However, a general guide for the chief results like those of M, μ, and R could be found in the last decimal which may be about 50 per cent in error.

In such an extensive compilation (in which some of my unpublished work was included) there is always a danger in being either quite objective, which may be connected with having no judgment, or having good judgment for some narrow fields but at the same time being very partial to the values published. I have tried to incorporate the good sides of both tendencies.

Sources for Table I

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CAMBRIDGE, MASS., JULY, 1944.

Note on Penumbral Lunar Eclipse

By ALICE H. FARNSWORTH

Photographs made on the night of July 5, 1944, again[1] gave evidence of a penumbral lunar eclipse which was wholly invisible to the eye. Exposures of 5^s each were made, with 2-inch aperture on the 8-inch visual refractor, on Eastman 50 plates behind a minus-blue filter: the first at 22^h 25^m E.S.T., 25 minutes after entry of the Moon into the penumbra; the second at 23^h 38^m, at mid-appulse. The second negative shows the region adjacent to the southern limb of the Moon appreciably fainter than a check region north of Mare Crisium, in contrast to the first plate where the relative brightness of the two regions is reversed.

[1] See account of February eclipse, POPULAR ASTRONOMY, **52**, 184, 1944.

The fourth and last of the penumbral lunar eclipses of 1944 will occur on December 29. The Moon will this time so nearly enter the umbra that the shading on the northern limb[2] will be clearly visible to observers, visual or photographic, in longitudes centered in the west Pacific Ocean.

[2] See diagram and details in POPULAR ASTRONOMY, **51**, 357, 1943.

JOHN PAYSON WILLISTON OBSERVATORY, SOUTH HADLEY, MASS.

Distribution of Planet Mass in the Solar System

By D. E. RICHARDSON*

ABSTRACT

It is assumed that the planets have grown through the continued accretion of mass under the influence of certain reasonable factors. Consideration of these factors leads to an equation $\log_e M_n = \log_e (M_0)_n + A \cdot F(n)$, where A is a constant and F (n) a function describing the favorableness to mass accretion due to the relative position of a planet in the system. In the development of the equation, $(M_0)_n$ is a limit of integration and represents the initial mass of the n-th planet. However, *it is found that an* F (n) *exists such that* $(M_0)_n$ *has the same value for all planets. This fact makes it possible to express planet mass in terms of planet ordinal number.* Concisely, planet mass is found to be given by $\log_e M_n = 6.80590\,\rho_n$. In this equation M_n is the mass of the n-th planet in terms of a unit mass equal to 46.3685×10^{-10} of the sun's mass and ρ_n equals the length of the radius vector of a simple circle-ellipse function [F(n)] corresponding to a polar angle $\pi n/5$. Except for Mercury and Pluto, whose observed masses are of recognized uncertainty, computed values of $\log_e M_n$ agree with observed values to within 0.14 of one per cent.

The purpose of this paper is to point out that the distribution of mass among the planets of the solar system is in correspondence with a relatively simple function of planet ordinal number.[1]

In time past, the planets of the solar system have grown by repeated or continuous gravitational acquisition of mass. Concerning the rate of such growth, it seems reasonable to suppose that the greater the mass of a given planet the better it has been able to compete in the acquirement of new mass; and we shall assume that this relation has been linear. It

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[1] The ordinal number of a planet denotes its remoteness from the sun. The values employed in this paper are as follows: Mercury (1), Venus (2), Earth (3), Mars (4), Jupiter (6), Saturn (7), Uranus (8), Neptune (9), and Pluto (10).

also seems reasonable to suppose that some positions in the system have favored accretion more than others; and we shall assume that this favoring has been in accordance with some well-defined function of ordinal number. Further, it may be argued that for any given position in the system the rate of increase in mass per unit mass of the corresponding planet has varied from time to time; and we will assume, simply, that this "factor of proportionality" has been "some function of time." These assumptions give us an over-all picture of planet growth that permits simple mathematical expression. Thus, we may write,

$$dm/dt = a\,(t) \cdot m \cdot F\,(n) \qquad (1)$$

where dm/dt is the time rate of mass increase for a planet of mass m and ordinal number n, a (t) the proportionality factor, and F (n) the function of ordinal number.

If the mass of the n-th planet is $(M_0)_n$ at zero time, and M_n its mass corresponding to $t = T$, then by equation (1),

$$\int_{(M_0)_n}^{M_n} dm/m = F\,(n) \cdot \int_0^T a\,(t)\,dt \qquad (2)$$

Evaluating the intergrals in this equation, we obtain

$$\log_e M_n - \log_e (M_0)_n = A \cdot F(n) \qquad (3)^2$$

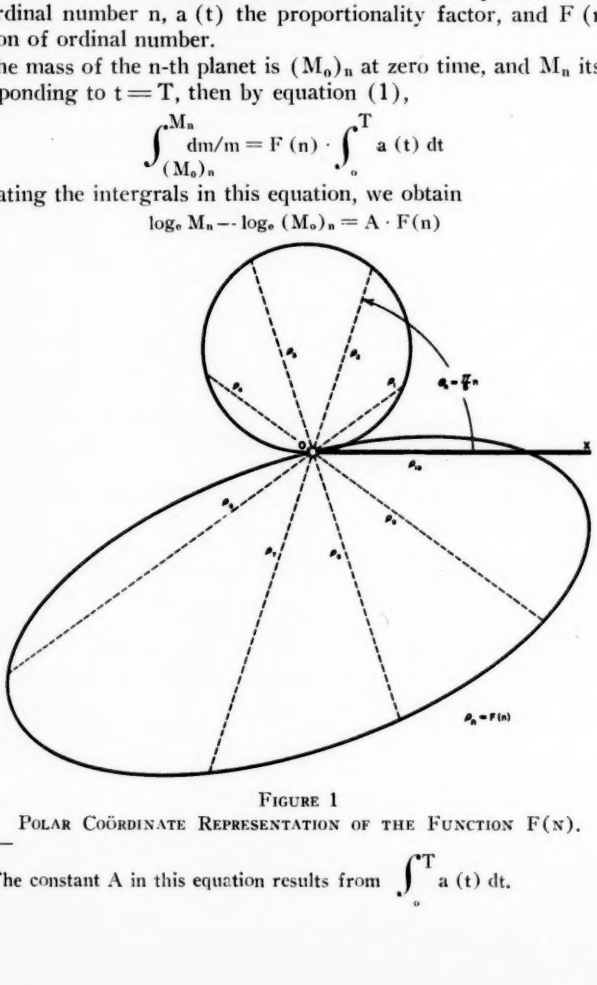


FIGURE 1
POLAR COÖRDINATE REPRESENTATION OF THE FUNCTION F(N).

[2] The constant A in this equation results from $\int_0^T a\,(t)\,dt$.

By the foregoing simple assumptions regarding planet growth, we have arrived at an equation relating a final mass M_n, an earlier mass $(M_0)_n$ and a function $F(n)$. However, the equation remains devoid of significance unless we can assign values to $\log_e (M_0)_n$, $F(n)$, and A such that the equation becomes true, or is satisfied, when any known value of planet mass M_n is substituted into it. Although no formal means is at our disposal, recourse to heuristic methods has revealed a function $F(n)$ that when used permits us to find a single numerical value for $\log_e (M_0)_n$ and one for A such that equation (3) becomes satisfied for any value of n. Following a description of this function, we first will describe means for finding suitable numerical values for $\log_e (M_0)_n$ and A; then, using values thus found, we will write equation (3) explicitly for $\log_e M_n$ and compare computed values of this quantity with those corresponding to known values of $\log_{10} M_n$ from the *American Ephemeris and Nautical Almanac*.

A polar coördinate represenation of $F(n)$ is shown in Figure 1. Radii vectores corresponding to the various values of planet ordinal number n are shown by dotted lines, and have polar angles given by $\theta = \pi n/5$. The function is a double function,[3] being circular for $1 \leq n < 5$ and elliptical for $5 < n \leq 10$. The circle and ellipse are uniquely specified in the drawing of Figure 2. Itemized, these specifications form the following sequence:

REFERRING TO FIGURE 2

1. $b/a = \sqrt{[(\pi-2)/(\pi+2)]}$; $ab = 1$
2. O_2O is normal to AB
3. $\angle XOM' = \pi/4$
4. $\alpha = a-1$; $\beta = a+b-1$
5. $R_0 = O_1O$

Item 1 defines the form and size of the ellipse. By the condition $ab = 1$, the area of the ellipse equals that of a circle of unit radius. Item 2 determines the line O_2O whose intersection with the ellipse locates the pole O of the polar coördinate system. Item 3 locates the initial line OX of the polar coördinate system. OM, of which OM′ is an extension, is the maximum radius vector of the ellipse with respect to O; its location can be computed from the constants of the ellipse. Item 4 locates the center of the circle O_1; α and β being the rectangular coördinates of O_1 with respect to a set of axes coinciding with the major and minor axes of the ellipse. Item 5 gives the radius of the circle. These relations serve sufficiently to define the function.

[3] Double functions or function pairs are not uncommon among expressions for physical quantities. Examples exist in the cases: (a) for the magnetic field intensity inside and outside of an electrical conductor carrying current, and (b) for the gravitational field intensity inside and outside of a homogeneous sphere. The present situation exhibits a certain similarity to these cases. The orbit sizes of the majority of asteroids are such that they may be considered to have an ordinal number 5; hence, as in (a) and (b) we have a kind of physical boundary between regions corresponding to two mathematical forms.

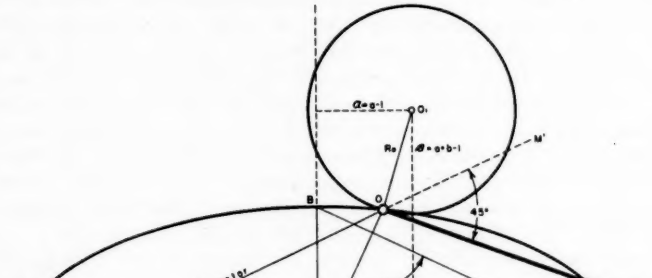


FIGURE 2
CONSTRUCTION OF THE CIRCLE AND ELLIPSE OF F(n).

Computed numerical constants pertaining to the circle and ellipse are as follows:

$$\begin{aligned} a &= [(\pi+2)/(\pi-2)]^{1/4} && = 1.456789 \\ b &= [(\pi-2)/(\pi+2)]^{1/4} && = 0.686441 \\ R &= \sqrt{[\pi\sqrt{(\pi^2-4)}/(\pi^2+4)]} && = 0.740790 \\ R_0 &= \ldots\ldots\ldots\ldots\ldots && = 0.493680 \\ e &= 2/\sqrt{(\pi+2)} && = 0.882026 \\ \angle O_2OM &= \sin^{-1}(2/\pi) && = 39°32'\,26'' \end{aligned}$$

The equation of the ellipse with respect to pole O and initial line OX is

$$\rho_n = \sqrt{(2)}\,\pi^{3/2}\frac{(\pi^2-4)^{1/4}}{(\pi^2+4)^{1/2}} \times \frac{[4+\sqrt{(\pi^2-4)}]\sin(\pi n/5) - [4-\sqrt{(\pi^2-4)}]\cos(\pi n/5)}{4\sin(2\pi n/5) + 2\sqrt{(\pi^2-4)}\cos(2\pi n/5) - \pi^2} \qquad 5 < n \leqslant 10 \tag{4}$$

and that of the circle in this same system of polar coördinates is

$$\rho_n = 0.987360\sin[(\pi n/5) - 3°\ 10'\ 18''] \qquad 1 \leqslant n < 5 \tag{5}$$[4]

Values of ρ_n computed from these formulas appear in Table I.

[4] The constant 0.987360 in this equation equals $2R_0$ and the angle 3° 10′ 18″ is the angle between OX and a tangent to the circle at O.

TABLE I

VALUES OF ρ_n COMPUTED FROM EQUATIONS (4) AND (5)

n	ρ_n	n	ρ_n
1	0.5352709	6	1.8006123
2	0.9207149	7	1.6173411
3	0.9544770	8	1.3449344
4	0.6236615	9	1.3653190
5	0.0546283	10	1.0332472

Equation (3) now can be written

$$\log_e M_n = \log_e (M_0)_n + A \cdot \rho_n \qquad (6)$$

where numerical values for ρ_n can be obtained from equations (4) and (5), or Table I. We yet must find suitable numerical values for $\log_e (M_0)_n$ and A.

Now, equation (6) is linear in $\log_e (M_0)_n$ and A. Hence, if for a given planet we assume various numerical values of A, and compute corresponding values of $\log_e (M_0)_n$ that exactly satisfy[5] equation (6), a plot of the latter against the former will be a straight line. Any point on this straight line then represents a pair of values for $\log_e (M_0)_n$ and A that will satisfy equation (6) in the case of the given planet. Straight lines determined in this way for each of the planets are plotted in

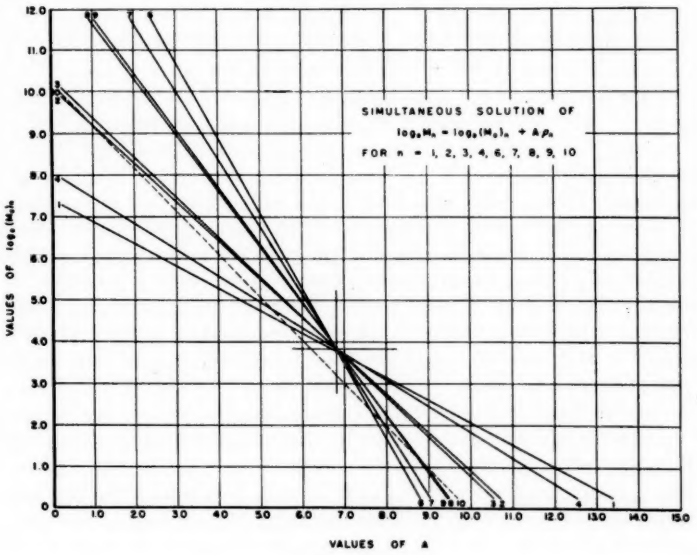


FIGURE 3

STRAIGHT LINES REPRESENTING PAIRS OF $\log_e (M_0)_n$ AND A THAT EXACTLY SATISFY EQUATION (6) FOR VARIOUS VALUES OF N.

[5] When using the value of ρ_n from Table I and the known value of $\log_e M_n$ for this planet.

Figure 3. With the exception of Pluto's, *all of these straight lines pass close to a certain fixed point, indicating the existence of a single value for* $\log_e (M_0)_n$ (which we may call $\log_e M_0$) *and one for* A *that will cause equation* (6) *to be satisfied simultaneously for all values of* n. The most probable values of A and $\log_e M_0$ can be evaluated from observation equations utilizing present known values of $\log_e M_n$ for the various planets. Observation equations for the planets Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune[6] appear in Table II.

TABLE II

OBSERVATION EQUATIONS FOR THE DETERMINATION OF A AND $\log_e M_0$

n	$\rho_n \cdot A$	+	$\log_e M_0$	=	$\log_e M_n$[7]
2	0.9207149A	+	$\log_e M_0$	=	10.1068284
3	0.9544770A	+	$\log_e M_0$	=	10.3208532
4	0.6236615A	+	$\log_e M_0$	=	8.0810373
6	1.8006123A	+	$\log_e M_0$	=	16.0718326
7	1.6173411A	+	$\log_e M_0$	=	14.8648757
8	1.3449344A	+	$\log_e M_0$	=	12.9883133
9	1.3653190A	+	$\log_e M_0$	=	13.1374771

Solution of these for the most probable values of A and $\log_e M_0$ gives

$$A = 6.80590$$
$$\log_e M_0 = 3.836620$$

Substituting these values for A and $\log_e (M_0)_n$ in equation (6) gives

$$\log_e M_n = 3.836620 + 6.80590\,\rho_n \qquad (7)$$

This equation has evolved from equation (3) by finding a suitable function for F (n) and suitable numerical values for A and $\log_e (M_0)_n$. *By means of the equation the mass of a planet can be evaluated from its ordinal number alone.* We are now in a position to test our premise that the distribution of mass among the planets of the solar system is in correspondence with a relatively simple function of planet ordinal number. With this end in view, values of $\log_e M_n$ computed by equation (7) are compared with known values of this quantity in Table III. Inspection reveals that the agreement is good; on a percentage basis differences range from 0.002 to 0.14 of one per cent except for Mercury and Pluto; and even for Mercury the difference amounts only to 0.8 of one per cent.

While we have reached our principal objective in demonstrating a close connection between planet mass and planet ordinal number, certain matters seem to call for further comment.

The equality among the values $(M_0)_n$ makes it appear [in the light of equations (1) and (2)], that the building of planet mass has taken place *as if* all planets started at some remote time with the same initial

[6] Equations of Mercury and Pluto have been omitted because of the commonly recognized uncertainty in the determinations of their masses.

[7] These values correspond to known values of $\log_{10} M_n$ taken from "Astronomical Constants" in the *American Ephemeris and Nautical Almanac*, in which the sun's mass may be taken as 10^{10}.

TABLE III

VALUES OF LOG$_e$ M_n COMPUTED BY FORMULA (7) COMPARED WITH KNOWN VALUES

n	ρ_n	Calculated log$_e$ M_n	Known log$_e$ M_n	Δ	Δ/log$_e$ M_n
1	.5352709	7.479620	7.418581	+ .061039	+ .00823
2	.9207149	10.102914	10.106828	— .003914	— .000387
3	.9544770	10.332695	10.320853	+ .011842	+ .001147
4	.6236615	8.081198	8.081037	+ .000161	+ .0000199
5	.0546283	4.208415	.....	.....	.....
6	1.8006123	16.091407	16.071833	+ .019574	+ .00122
7	1.6173411	14.844082	14.864876	— .020794	— .00140
8	1.3449344	12.990109	12.988313	+ .001796	+ .000138
9	1.3653190	13.128845	13.137477	— .008632	— .000657
10	1.0332472	10.868797	10.246775	+ .622022	+ .06070

mass and that they since have been acquiring it according to $dm/dt = a(t) \cdot m \cdot F(n)$. If we argue that it is unlikely that all planets should have had equal masses at any particular time, we are led to extend our picture of events and conclude that when a planet has had a deficiency in mass, it has been caused to depart from its position in space under the gravitational influence of the relatively greater masses, so that for a time its position became more favorable for the acquisition of mass. It here acquired mass at greater than its expected or normal rate so that eventually equilibrium was established or re-established, both as to position and mass. This view still permits us to say that the distribution of mass among the planets of the solar system *is as if* they once possessed equal masses of value M_0 and since have been acquiring it at rates given by $dm/dt = a(t) \cdot m \cdot F(n)$ resulting in a relative distribution of character demonstrated.

To inquire further into the physical significance of M_0 let us refer to Figure 1 and equation (6). In Figure 1 we note that both circle and ellipse pass through the polar origin and that, therefore, $\rho_n = 0$ is a special value of either function for any value of n. In equation (6) we note that for $\rho_n = 0$, we have $\log_e M_n = \log_e M_0$.[8] Hence $M_n = M_0$ may be regarded a special solution for the mass corresponding to any planet position.

The size of M_0 in terms of sun's mass equal to 10^{10} is $\log_e^{-1} 3.836620$ or 46.3685. Hence, M_0 equals 46.3685×10^{-10} of the sun's mass. This corresponds to approximately 1/700 of the earth's mass, which in turn agrees with estimates[9] that have been made for the "mass of all the asteroids, known and unknown." This seems of possible significance, since we have found that M_0 is a special solution for the mass corresponding to any value of ordinal number. On the other hand, the calculated mass corresponding to ordinal number 5 (of the circle) is ap-

[8] Calling $(M_0)_n = M_0$.

[9] In *Astronomy*, Vol. I, by H. N. Russell, R. S. Dugan, and J. Q. Stewart, we read on page 353, ". . . but from existing evidence it seems that 1/1000 of the earth's mass is a reasonable estimate, and 1/500 a liberal estimate, for the mass of all the asteroids, known and unknown."

proximately 1/450 of the earth's mass; and it may be more natural to associate total asteroid mass with planet ordinal number 5 since the majority of asteroids have orbit sizes greater than that of Mars (4) but less than that of Jupiter (6).

By using M_0 as the unit of mass in the solar system, equation (7) becomes simplified to

$$\log_e M_n = 6.80590\,\rho_n \tag{8}$$

where M_n is the mass of the n-th planet in terms of M_0 as unit mass. Table IV gives values of M_n and $\log_e M_n$ based on *known* masses for the various planets. For comparison, values of $6.80590\,\rho_n$ are tabulated.

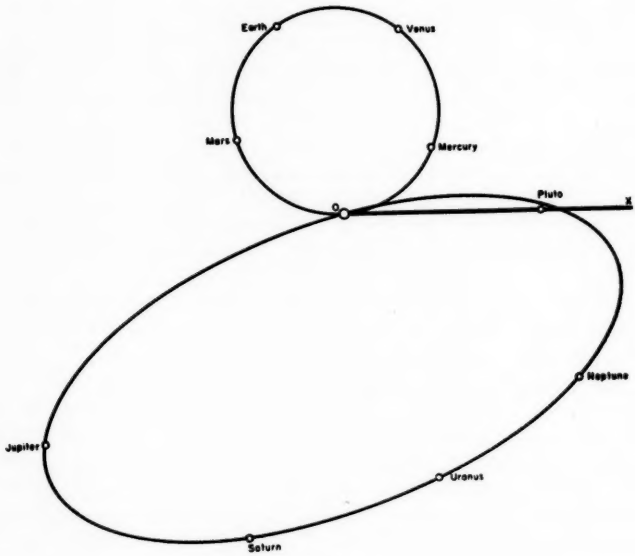


FIGURE 4

KNOWN VALUES OF $\text{LOG}_e M_n$ CAREFULLY PLOTTED IN POLAR COÖRDINATES AGAINST VALUES OF $\pi N/5$. CIRCLE AND ELLIPSE ACCURATELY REPRESENT $6.80590\,\rho_n$.

Known values of $\log_e M_n$ (from Table IV) are plotted directly against $\pi n/5$ in Figure 4. In the preparation of this figure, the points have been very carefully placed so that their deviations from the circle-ellipse function are accurately portrayed. The evident agreement of known-value points with their expected positions in the circle-ellipse constitutes a final demonstration of our premise that the distribution of mass among the planets of the solar system is in correspondence with a relatively simple function of planet ordinal number.

TABLE IV

VALUES OF M_n[10] AND OF $\log_e M_n$ BASED ON KNOWN VALUES OF $\log_{10} M_n$[11] FOR THE VARIOUS PLANETS; INCLUDING VALUES OF $6.80590\,\rho_n$ FOR COMPARISON. SEE EQUATION (8).

n	Planet	$\log_e M_n$	M_n	$6.80590\,\rho_n$
1	Mercury	3.581961	35.94	3.643000
2	Venus	6.270208	528.59	6.266294
3	Earth	6.484233	654.74	6.496075
4	Mars	4.244417	69.72	4.244578
5				
6	Jupiter	12.235213	205,914.	12.254787
7	Saturn	11.028256	61,590.	11.007462
8	Uranus	9.151693	9,430.	9.153489
9	Neptune	9.300857	10,947.	9.292225
10	Pluto	6.410155	608.	7.032177

[10] Masses M_n are in terms of unit mass equal to 46.3685×10^{-10} of sun's mass.

[11] Values of $\log_{10} M_n$ were taken from "Astronomical Constants" in the *American Ephemeris and Nautical Almanac*.

The Planets in January, 1945

NOTE: Greenwich Civil Time is employed unless otherwise stated. To obtain Eastern War Time subtract 4 hours, Central War Time, 5 hours, etc. The phenomena are described as they are to be seen from latitude 45° N. The data are taken chiefly from the *American Ephemeris and Nautical Almanac*.

Sun. The sun will move northward from —23° 3′ to —17° 32′ during January. Its eastward motion will take it from Sagittarius into and nearly through Capricornus. It will not pass near any bright stars during this period. On January 14 will occur an annular eclipse of the sun. This will be of little interest because the path lies almost entirely over the Indian and the South Pacific Oceans.

Moon. The phases of the moon will occur as follows:

	d	h
Last Quarter	Jan. 6	13
New Moon	14	5
First Quarter	21	0
Full Moon	28	7

It will be farthest from the earth on January 6 and nearest to the earth on January 17.

Mercury. Having passed inferior conjunction on December 23, Mercury's apparent eastward motion will be less rapid than that of the sun. It will come to a point of greatest elongation west of the sun on January 13. On and near this date, Mercury will be visible near the eastern horizon just before sunrise. It will appear at very nearly the same point on the horizon as the sun, their declinations differing by about one degree.

Venus. Throughout the month, Venus will be the brilliant evening star, high in the sky at sunset. Its brilliancy will identify it for the most casual observer. It will move nearly fifteen degrees northward during the month.

Earth. On January 2 the earth will be at perihelion, that is, nearest the sun for the year.

Mars. Mars will still be quite near the sun in the sky. On the average

throughout the month it will rise a little more than an hour before the sun. It will be more than twenty degrees south of the equator during this period. It will be moving toward the earth.

Jupiter. Jupiter will change its position very little during this period. It will move eastward slowly until December 12, on which date it will begin a long period of retrograde motion. As last month, its position will be nearly midway between Regulus and Spica. It will be observable in the early morning hours.

Saturn. Saturn will be most favorably situated for observation. Being near opposition it will be above the horizon practically all night. Its large northern declination is favorable for northern observers. Its motion continues to be retrograde. It will be in Gemini slightly preceding The Twins.

Uranus. As in preceding months, Uranus will be about two hours west of Saturn. It will be in Taurus, quite near Aldebaran. However, if visible at all to the naked eye, it will not be distinguishable from a faint star. A small telescope will reveal its disk.

Neptune. Neptune will still be above the horizon only after midnight. For those who may wish to locate it by means of setting circles, we give its position on January 15 as, $\alpha = 12^h\ 26^m$; $\delta = -1°\ 14'$.

Pluto. The position of Pluto, as given by the Nautical Almanac Office of the United States Naval Observatory, on January 17 will be, $\alpha = 8^h\ 54^m6$; $\delta = +23°\ 42'$.

Asteroid Notes

By HUGH S. RICE

JUNO. This asteroid is in Orion in a good place for observation, and is making a turn to retrograde. We have been observing it satisfactorily with Zeiss 50-mm glass. The magnitude shows it particularly bright for this planet, the visual magnitude near the end of November being about 7.2. It is expected to get brighter yet (7.0) around opposition, December 24. (Juno is easy enough to observe that we could discern it from indoors looking out, with the window closed; a more enhanced view however was achieved with the window open. As yet this fall we have not been forced to move farther outdoors for observation than the window-sill.)

IRIS. This planet, in southern Leo, is comparatively faint (magnitude 9.9 around January 5), but is becoming brighter and will probably reach 9.0 in early March.

PALLAS. We have just commenced observations on this asteroid. It was observable in Crater, around $5^h\ 40^m$, local civil time. According to the apparent path as plotted, it is practically coincident with the star Iota Crateris on December 11, 0^h U.T. At the end of December the visual magnitude is about 7.8, thus putting the object within reach of small instruments.

VESTA and CERES. These are beginning their apparition again, both in Virgo, the former north of Spica, and the latter east of Vesta. We predict the magnitude of Vesta in January as 8.6 and of Ceres as 8.9. Because of their positions in the heavens, Pallas, Vesta, and Ceres are all "morning star" planets, so to speak, and at present observable just before dawn.

The following ephemerides are furnished by Dr. Dirk Brouwer of Yale University Observatory.

EPHEMERIDES OF ASTEROIDS 0^h U.T.

3 JUNO (EQUINOX 1944.0)

1944	α h m	δ ° ′	1945	α h m	δ ° ′
Dec. 16	6 12.1	− 0 41	Jan. 5	5 55.2	+ 0 31
21	6 7.8	− 0 35	10	5 51.8	+ 1 7
26	6 3.4	− 0 21	15	5 49.1	+ 1 48
31	5 59.1	+ 0 1	20	5 47.0	+ 2 33

7 IRIS (EQUINOX 1945.0)

1944	α h m	δ ° ′	1945	α h m	δ ° ′
Dec. 16	11 24.2	− 2 18	Jan. 5	11 34.6	− 4 27
21	11 27.6	− 2 55	10	11 35.6	− 4 50
26	11 30.5	− 3 29	15	11 36.0	− 5 9
31	11 32.8	− 4 0	20	11 35.7	− 5 24

2 PALLAS (EQUINOX 1945.0)

1944	α h m	δ ° ′	1945	α h m	δ ° ′
Dec. 16	11 42.5	−13 2	Jan. 5	12 4.9	−12 41
21	11 48.7	−13 5	10	12 9.3	−12 20
26	11 54.6	−13 3	15	12 13.2	−11 51
31	12 0.0	−12 55	20	12 16.4	−11 14

4 VESTA (EQUINOX 1945.0)

1944	α h m	δ ° ′	1945	α h m	δ ° ′
Dec. 16	12 38.1	+ 2 32	Jan. 5	13 3.8	+ 0 59
21	12 44.9	+ 2 5	10	13 9.5	+ 0 43
26	12 51.5	+ 1 40	15	13 14.8	+ 0 31
31	12 57.8	+ 1 18	20	13 19.7	+ 0 22

1 CERES (EQUINOX 1945.0)

1944-45	α h m	δ ° ′	1945	α h m	δ ° ′
Dec. 26	13 44.4	− 0 22	Jan. 10	14 2.9	− 1 32
31	13 50.8	− 0 48	15	14 8.5	− 1 50
Jan. 5	13 57.0	− 1 11	20	14 13.7	− 2 5

Hayden Planetarium, American Museum of Natural History, New York, N. Y., November 27, 1944.

Occultation Predictions for January, 1945

(Taken from the *American Ephemeris*)

Date 1945	Star	Mag.	IMMERSION Greenwich C.T. h m	IMMERSION a m	IMMERSION b m	IMMERSION Angle E from N °	EMERSION Greenwich C.T. h m	EMERSION a m	EMERSION b m	EMERSION Angle E from N °
OCCULTATIONS VISIBLE IN LONGITUDE +72° 30′, LATITUDE +42° 30′										
Jan. 23	302 B.Taur	6.1	22 7.2	−0.6	+2.1	52	23 15.9	−1.6	+1.0	267
24	*i* Taur	5.1	1 10.0	−2.7	−2.2	126	2 0.0	−1.3	+3.7	201
24	312 B.Taur	6.2	3 42.9	−1.6	+3.4	21	4 21.5	−1.0	−4.4	320
25	BD+20°1105	5.9	1 0.1	−2.5	−1.8	130	1 51.3	−1.3	+3.8	207
26	*d* Gemi	5.2	4 26.2	−1.7	−2.1	123	5 37.0	−1.8	+0.1	245

	Occultations Visible in Longitude +91° 0′, Latitude +40° 0′											
Jan. 23	302 B.Taur	6.1	21	56.5	+0.1	+2.4	33	22	47.9	−1.2	+0.7	286
24	*i* Taur	5.1	0	26.9	−2.0	+0.2	107	1	29.9	−1.1	+2.8	213
24	312 B.Taur	6.2	3	5.6	−1.4	+3.3	26	4	0.2	−2.2	−2.8	305
24	333 B.Taur	6.5	8	45.1	−0.7	+0.9	32	9	17.7	+0.8	−2.9	321
25	BD+20°1105	5.9	0	22.4	−1.6	+0.3	112	1	22.7	−0.9	+2.9	219
26	*d* Gemi	5.2	3	54.9	−2.3	−2.6	136	4	54.4	−2.2	+2.8	222
	Occultations Visible in Longitude +120° 0′, Latitude +36° 0′											
Jan. 5	*c* Virg	5.1	7	52.2	−0.2	+2.8	62	8	33.9	−0.4	−2.2	343
22	3 B.Taur	6.4	7	11.9	−1.0	+2.1	21	7	52.1	−0.3	−3.0	305
23	*i* Taur	5.1	23	50.2	−0.4	+1.4	77	0	54.0	−0.7	+1.8	243
24	333 B.Taur	6.5	8	19.9	−1.2	−0.6	76	9	28.0	−0.6	−1.3	274
24	BD+20°1105	5.9	23	56.0	−0.1	+1.2	85	0	55.4	−0.3	+1.7	246
26	*d* Gemi	5.2	2	55.8	−1.6	−0.2	121	3	54.2	−1.0	+3.1	222
	Occultations Visible in Longitude +98° 0′, Latitude +30° 0′*											
Jan. 5	*c* Virg	5.1	7	55.8	−1.3	+1.5	84	9	1.2	−1.0	−2.0	333
21	BD+6°324	6.9	0	9.5	−1.3	+2.3	32	..	..	..	..	...
22	3 B.Taur	6.4	7	20.3	−0.4	+0.8	38	8	4.3	+0.4	−1.7	295
23	302 B.Taur	6.1	21	36.3	+0.2	+1.8	49	22	32.2	−0.7	+1.0	270
23	305 B.Taur	6.8	22	37.8	−0.8	+0.8	97	..	..	..	..	...
24	*i* Taur	5.1	0	15.9	−3.5	−2.4	134	0	46.8	..	..	182
24	312 B.Taur	6.2	2	29.9	−2.0	+1.7	57	3	56.6	−2.5	−0.1	267
24	333 B.Taur	6.5	8	41.7	−0.4	−0.6	77	9	38.7	+0.2	−1.1	278
24	107 Taur	6.6	10	6.5	+0.1	−0.4	72	..	..	..	..	...
25	BD+20°1105	5.9	0	14.6	−2.8	−2.4	140	0	42.1	..	..	186
25	231 B.Orio	6.7	7	9.7	−1.8	0.0	69	..	..	..	..	...

*Computation by George R. Schaefer and Paul Herget, communicated by Captain V. K. Coman, Superintendent U.S. Naval Observatory.

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

On the morning of 1944 August 18 at about 8:12, C.W.T., a very remarkable fireball or bolide appeared over Ohio, crossed Indiana, and ended over Illinois. My first notice was a brief item in the paper, but a day later Mr. Watson Davis, director of Science Service, called me by long-distance about it. His kind offer to telegraph to all the papers on his list in the general region was accepted, and he wired my request for reports. Consequently this, in correct or slightly garbled form, promptly appeared in many papers of Indiana, Kentucky, and Ohio, and perhaps in Illinois and Michigan. As a result of this excellent cooperation about 250 reports were received, besides numerous newspaper clippings. A certain

number of reports were good enough or important enough to follow up, and A.M.S. Bulletin No. 13 was sent to some of those reporting. Formal acknowledgment cards were mailed to every observer. On the basis of these reports work was at once started on a solution. All the preliminary codification, measuring of coordinates of stations, etc., was done by Miss Edith F. Reilly. She also made the first plots of azimuths. She, however, being called to the Naval Observatory, I took up the work where she had left off and, checking certain parts, pushed it to the conclusions which follow.

Before describing the fireball itself, some remarks should be made about the method of determining its path. Coming in full daylight, it suffered from the disadvantage of having no objects in the sky except the Sun for comparison. Only three observers attempted to use this, and then only in a most approximate manner. Also the path of 546 km was so long that most observers did not see but a portion of it—few indeed the very first part. The small number who gave compass directions, as a rule, saw but part of the whole. Therefore the great majority, if they attempted to give directions, perforce did it by estimation. On the good side, however, for those near, an enduring smoke-train outlined the latter part of the path where the object had a lower altitude. Also there were several observers, almost in the plane of its motion, who reported the path as vertical. Five points were selected for solution: beginning point, point of first explosion, point of second explosion, end point, and ground point. Careful study of the reports permitted me to sift out which of the first four points the observer had in mind, without too much chance for error. Then plotting the azimuth lines I marked all stations near the probable projected path showing whether the latter was north or south of their zeniths. This narrowed greatly the possible strip of country it *could* be over. All reports which gave a vertical or nearly vertical path were then combined with the above to choose the exact direction of motion. The result was most gratifying and the azimuth of the path seems derived with considerable accuracy. The Joliet Astronomical Society reported seven observations made in such a way that they were valuable particularly for determining the end and ground points. For the actual beginning point only two observers gave anything which could be used, saying in effect that the fireball started near the Sun. The latter's actual altitude and azimuth, determined from a globe, were used as their observation. To determine points on the path, the distance of the projected path from each station was measured, and the altitude angles, corrected for the Earth's curvature, used to compute the heights. Besides the four points mentioned, each of which depends upon the mean of a group of observations, several other isolated points are available; also the two at the beginning. To my considerable surprise a straight line drawn through the mean points fits them all excellently, and hence gives confidence in the derived slope of the path. I made no direct use of the various angles of slopes estimated by various observers. In too many of these cases there was no way of isolating the part of the path they referred to. Most, however, who were well to the side of the path, reported that its angle with the ground was small. This bears out the computed result. I rarely remember handling a case in which, when averaged in, the data so corroborated themselves in the sense that each part of the solution somewhat checked the other parts.

The results are tabulated as follows.

Date	1944 Aug. 18, 7:12 A.M., C.S.T., = Aug. 18.55 G.C.T.
Began over	$\lambda = 82° 12'$, $\phi = +40° 02'$ at 166 km, 2 observers

Ended over	$\lambda = 88° 12', \phi = +38° 44'$ at 31 km, 6 observers
First explosion over	$\lambda = 86° 28', \phi = +39° 06'$ at 69 km, 5 observers
Second explosion over	$\lambda = 87° 29', \phi = +38° 53'$ at 46 km, 13 observers
Ground point	$\lambda = 89° 26', \phi = +38° 27'$ at 0 km
Sidereal time at ground point	75° 23′
Length of path	546 km
Projected length of path	529 km
Velocity (apparent, geocentric)	31 km/sec (last half of path)
Radiant (uncorrected)	$a = 252°.5$, $h = 11°.6$
Zenith correction (parabolic)	—5°.4
Radiant (corrected)	$a = 252°.5$, $h = 6°.2$; $\alpha = 169°.3$, $\delta = +17°.6$
Parabolic orbit:	
Longitude of meteoric apex	56°.1
i	7.3
☊	145.4
π	266.5
q	0.763

Brilliancy and Apparent Size: It is most difficult for even a trained observer to estimate the brilliancy of an object seen in the day sky, which on this morning was reported as very clear in most places. Also the object was naturally much brighter to those near its path. That its light was unusually intense is borne out by several stating that it was "bright as the Sun." A number of others stated that its disk was as large as the full Moon. I see no way of getting a quantitative value of the object's magnitude. It can only be classed as very brilliant. The estimates of the disk's angular diameter may be accepted with more confidence, as representing the size of the head, which was of course mostly the hot vapors accompanying the solid nucleus. Many thought at first that it was a burning plane, and robot bombs were in the minds of others. A "ball of fire" was a frequent expression. Several drawings, some in color, were submitted. The object, at first silver-white, grew yellow then red as it neared its end. However, all the colors of the rainbow were mentioned by some one or other for its fiery, trailing tail. The head was oval-shaped, the long axis in the direction of motion. Behind it was a tail of hot, colored gases, trailing with it, some ten to fifteen times as long as the head's diameter. This appendage is not to be confused with the long-enduring smoke-train that remained along the path.

Explosions and Smoke Train: The data indicate two points at which special "explosions" took place. The first, E_1, as reported by some careful observers, consisted of the separation of the head into two or three pieces which continued straight on their course. The second point, E_2, was probably that of general disintegration, the fragments continuing nevertheless some 67 km farther to point E. E_1 was at 69 km height, E_2 at 46 km, and E_1E_2 was 94 km long. The long-enduring smoke-train seems to have extended from E back beyond E_2, but not to E_1 by any means. The upper end was probably 55 km high, the lower being at E was 31 km. These values, secured *before* I looked up the reference, are in splendid agreement with the means given in *F. O. Reprint* No. 60 for similar cases which are 57 km and 30 km, respectively. The smoke-train was not seen at great distances. It is described as resembling sky-writing in intensity, which explains the statement just made, as sky-writing is only visible from relatively near points. Observers estimate its visibility from one-half minute to 20 minutes; 5 to 10 minutes would be the interval it retained full coherence, though in a diffused state it probably lasted fully twice as long. The wind velocity in this 31-55 km stratum was quite low. A slight drift to the south and to the east is indicated; no numerical result is possible as no data are

given on its angular motion. One observer in the plane of the path indicates a zig-zag line as representing the last stages. As this is almost certainly correct, there were 3 to 5 very slight north-south components at different levels. Many report "no motion" or simple "diffusion." It is best, however, to conclude that there was a wind in the stratum in question of low velocity, blowing towards the S.E.

Sounds: Anything like loud sounds or explosions were heard by only a small number of our observers, all just north or south of the portion $E_1 E_2 E$ of the path. Many positively state that they heard none, but they were in general farther away. The following places reported loud sounds: Bicknell, Carlisle, Heltonville, Paoli, Petersburg, Sullivan, Terre Haute, Vincennes, Washington, and Youngstown, all in Indiana, and Lawrenceville, Ill. At Carlisle the ground shook, a jar was felt at Terre Haute, and windows rattled at Youngstown. At places distant from the path we had some observers report a "hissing" or "swishing" simultaneous with the fireball. Obviously an ordinary sound effect is impossible and it might be dismissed as mere imagination *except* that several say such an effect caused them to turn and see the meteor! I leave to my colleagues who deal with electrical and radio effects whether and how the passage of a fireball can produce such a phenomenon as described.

Velocity: As usual the most uncertain datum is the velocity. Seven observers gave the time the fireball took to cover a given part of its path, which could be identified approximately. From these, covering in general the last half of the path, I find an apparent velocity of 31 ± 18 km/sec. This is the part, obviously, where atmospheric resistance was steadily growing greater than in the first part. Six observers in Kentucky, who did not see the end point, and may be presumed to have seen the middle 50% of the path, more or less, gave a duration of 3.1 ± 0.8 sec. This would roughly indicate a velocity of 88 km/sec, which is strongly hyperbolic. Most others, who mention it at all, speak in terms of a high velocity. Six only indicate by number of seconds or description that they considered the velocity low. It seems safest to assume a parabolic heliocentric velocity, as the observed velocities have such extremely low weight and refer to parts of the path only. In the fireball catalogue of von Niessl-Hoffmeister, fireball No. 570 on 1921 August 17, has almost exactly the same radiant as this object. It also was spectacular and detonating. Hoffmeister, in *Sonneberg Mitt.*, Nr. 2, gives a full description and derives a strongly hyperbolic orbit. He considers his data sufficiently good to show a constant deceleration for the lower part of the path. Though his average velocity was only 37 km/sec, by extrapolation he derives 57 km/sec for the true heliocentric velocity. A similar (but in this case wholly unjustified) treatment of our data would give a hyperbolic orbit also.

General Remarks: Pages could be filled with more or less interesting notes on the reaction of observers, including a few who were so sure that the fireball had landed near them. Actually, the chances seem rather good that fragments did fall, and they should be sought for, I think, beyond E, in the line of motion. This would be in the vicinity of Parkersburg in Richland County, Ill., and is about 15 to 20 miles north of the preliminary end point, derived from the first batch of reports and which was furnished by me to Science Service, and by them published. It is probable that the beginning point was really higher and farther east than given but, if so, there are no reliable observations to prove it. The total lack of reports from that part of Illinois near and beyond the calculated end

point has been a considerable handicap in my solution. As Indiana and Kentucky, and to a lesser degree Ohio, showed up so well in the number of reports, this lack is not understood unless the area was cloudy. As should have been obvious from the time of day and direction of motion the fireball could not have come from the Perseid radiant and had nothing to do with that stream. If the papers correctly quoted several astronomers and meteorologists, it is a pity that the latter jumped to the conclusion, without investigation, that it was a Perseid fireball. This serious piece of misinformation was widely published in newspapers. Incidentally no meteorite was ever known to come from the Perseid radiant and we hope some may be found this time. Something picked up at Danville, Ill., purporting to be a meteorite, even if authentic could have nothing whatever to do with this fireball.

In acknowledgment, to Mr. Watson Davis of Science Service I owe nearly all the reports. To Miss E. F. Reilly my thanks are due for arranging the data and preliminary work. And lastly to the 250 ± individuals who took the trouble to write me and in many cases send in additional reports, I wish to extend my sincere thanks. Without them no solution would be possible.

Note: Since completing this paper I learned that Professor C. C. Wylie spoke at the A.A.A.S. meeting at Cleveland on this fireball. No details are given of his conclusion. It is a great pity that all the data on the same object were not in the hands of one person so that the best results might be obtained. As it is, he probably had data from near the end point region in which my solution is weakest.

Flower Observatory of the University of Pennsylvania, Upper Darby, Pennsylvania, 1944 October 30.

Contributions of the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD
Department of Astronomy, University of California, Los Angeles 24

The Co-ordinate Numbers and Classification of the Quartz Mountain and Quinn Canyon, Nevada, Siderites

FREDERICK C. LEONARD
Department of Astronomy, University of California, Los Angeles

ABSTRACT

The coördinate numbers and classification of the Quartz Mountain and Quinn Canyon, Nye County, Nevada, siderites are given. Quartz Mountain, which closely resembles a typical Canyon Diablo, Arizona, iron, is apparently a very old fall, while Quinn Canyon is doubtless a much later arrival on the planet.

In the course of a recent visit (May, 1944) at the University of Nevada in Reno, I was privileged to examine the main mass and a small fragment of the beautiful little 4.832-kg. Quartz Mountain siderite[1] and also a bit of the great Quinn Canyon siderite, the third largest meteorite on record for the United States. The latter iron, which weighs 1450 kg., constitutes the principal "show-piece"

in the collection at the Chicago Natural History Museum. Both meteorites are unwitnessed falls and both came from Nye County. The Quartz Mountain specimen "was discovered April 24, 1935, 5 miles southeast of Quartz Mountain, in central Nevada"[1]; thus, its coördinate number[2] may be assumed to be 1167,372. "The only other, definitely determined, meteorite from Nevada is the Quinn Canyon iron, discovered in 1908, from the Quinn Canyon Range, 100 miles east of Tonopah."[1] From this description it would seem that the point of find must be very near to a place called "Sharp." The coördinate number of Sharp is 1154,381, which may accordingly be adopted—at least provisionally—as the coördinate number of the meteorite.

From measures of the width of the Widmanstätten bands on etched surfaces of the forementioned specimens, I would classify both Quartz Mountain and Quinn Canyon as coarse octahedrites (Og).[3] The thickness of the lamellae in the bit of Quinn Canyon ranges from 1½ to 2 mm., while the width of the bands in the main mass of Quartz Mountain varies from ¾ to 2½ mm., and, in the fragment, from 1 to 3 mm., the average width in the former case being perhaps 1¼ or 1½ mm. and in the latter, 1¾ or 2 mm. Taenite is not at all conspicuous in the fragment but is more readily discernible in the parent mass.

Quartz Mountain is evidently a very old fall; it shows not the slightest trace of a fusion crust and it closely resembles, not only superficially but also in its crystalline structure, a typical Canyon Diablo, Arizona, siderite, for which it might easily pass. Quinn Canyon, on the other hand, is probably a much more recent arrival on the planet, its earthly history dating possibly from 1894 February 1, when the concomitant meteor may have been observed;[1] still possessing a considerable quantity of well-preserved fusion crust and being almost perfectly conoid, it ranks as one of the finest large, oriented meteorites yet recovered.

REFERENCES AND NOTE

[1] V. P. Gianella, *P. A.*, **44**, 448-50, 1 fig., 1936.

[2] F. C. Leonard, *C.S.R.M.*, **3**, 153-5; *P. A.*, **52**, 306-7, 1944, and the sources cited in ref. and n. (1) and (2) therein.

[3] O. C. Farrington, *Meteorites*, under "Octahedrites," 202, 1915. The classification of Quinn Canyon, as quoted in the catalogs (*e.g.*, Prior's and Coulson's), is "medium octahedrite" (Om). This implies that the thickness of the lamellae is only ½ to 1 mm., according to the criteria listed by Farrington, *op. cit.*

The Identity of the "Windmill Station" with the "Valley Wells," California, Aerolitic Fall

FREDERICK C. LEONARD

ABSTRACT

The place names "Windmill Station" and "Valley Wells," California, refer to one and the same aerolitic fall, of which the coördinate number is 1157,355 and which should be known as "Valley Wells."

A recent check-up of the authenticated meteoritic falls of California has revealed the identity of the "Windmill Station" with the "Valley Wells" aerolitic fall. On p. 147 of the Appendix to H. H. Nininger's *Our Stone-Pelted Planet*, 1933, the following information is given for

"Windmill Station. Found 1929. One small fragment. Undescribed. Authority Barnum Brown."

In A. L. Coulson's *A Catalogue of Meteorites (Mem. Geol. Survey India*, 75,

1940), "Windmill Station" is entered, on pp. 226-7, thus:

"Windmill Station, California, U.S.A. Found 1929. Meteorite, Met.," while "Valley Wells" is separately recorded, on p. 220, as follows:

"Valley Wells, San Bernardino County, California, U.S.A. Found 1929 June 10. Stone. Gray chondrite, Cg."

Altho both places, Windmill Station and Valley Wells, are situated in San Bernardino County, a map reproduced in *The Griffith Observer* (Los Angeles), **4**, 7, 1940, incorrectly depicts the "Windmill Station" fall as being located in the extreme southeastern part of *Inyo* County, just north of the San Bernardino County line! The geographical coördinates of Valley Wells, as determined from a large-scale map, are

$$L = \text{W. } 115° 40', \quad l = \text{N. } 35° 28'.$$

Windmill Station is a mile or so south of Valley Wells.

The following rather detailed description of the "Valley Wells" fall is taken from pp. 633-4 of the *Catalogue of the Meteorites in The American Museum of Natural History As of October 1, 1935*, by Chester A. Reeds, Ph.D. (*Bull. Am. Mus. Nat. Hist.*, **73**, Art. 6, 517-672, 1937):

"Valley Wells, San Bernardino County, California, U. S. A. Found: 1929 June 10. Aerolite: Gray chondrite, Cg. Specimens: (2615) 10.5 g.; (2616) 13.5 g.; (2617) 24 g.; (2618) 81.9 g. Remarks: On June 10, 1929, Dr. Barnum Brown of the American Museum, after 35 years' experience as a collector, found his first meteorite. Four weathered pieces of a stony meteorite were picked up on a desert landscape, ½ mile north of Valley Wells, California. The weights are as noted above. The specimens were delivered to the Department of Geology of the Museum, April 28, 1930. The 4 pieces are considerably weathered, have a desert polish, and show considerable oxidation. The surface of one of the pieces has been polished. Unweathered parts indicate a gray chondrite (Cg) with isolated metallic points of nickel-iron scattered thruout the mass."

No mention is made in this *Catalogue* of a "Windmill Station" fall. The identity of "Windmill Station" with "Valley Wells" may therefore be regarded as proved. If the place of find of the specimens is "½ mile north of Valley Wells," the coördinate number of the fall is 1157,355; the fall should be known as "Valley Wells"; and the name "Windmill Station" should be discarded.

Death of C. B. Lipman

Dr. Charles Bernard Lipman, Professor of Plant Physiology and Dean of the Graduate Division of the University of California, Berkeley, after an illness of 10 days, died in Berkeley on 1944 October 22, at the age of 61 years. Dr. Lipman, who was a Fellow of the Society for Research on Meteorites, is known in meteoritics for his work on bacteria in meteorites; see, *e.g.*, his paper on that subject, published in *C.S.R.M.*, **1**, No. 2, 40-4; *P. A.*, **44**, 442-6, 1936.

President of the Society: Lincoln La Paz, Department of Mathematics, Ohio State University, Columbus 10

Secretary of the Society: C. H. Cleminshaw, Griffith Observatory, P. O. Box 9866, Los Feliz Station, Los Angeles 27, California

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

New Zealand Variable Star Observations: The first variable star memoir of the New Zealand Astronomical Society has just been issued. It contains a highly commendable report by Mr. Frank M. Bateson, on the study of variable stars as observed by that section during the the years 1927-1940.

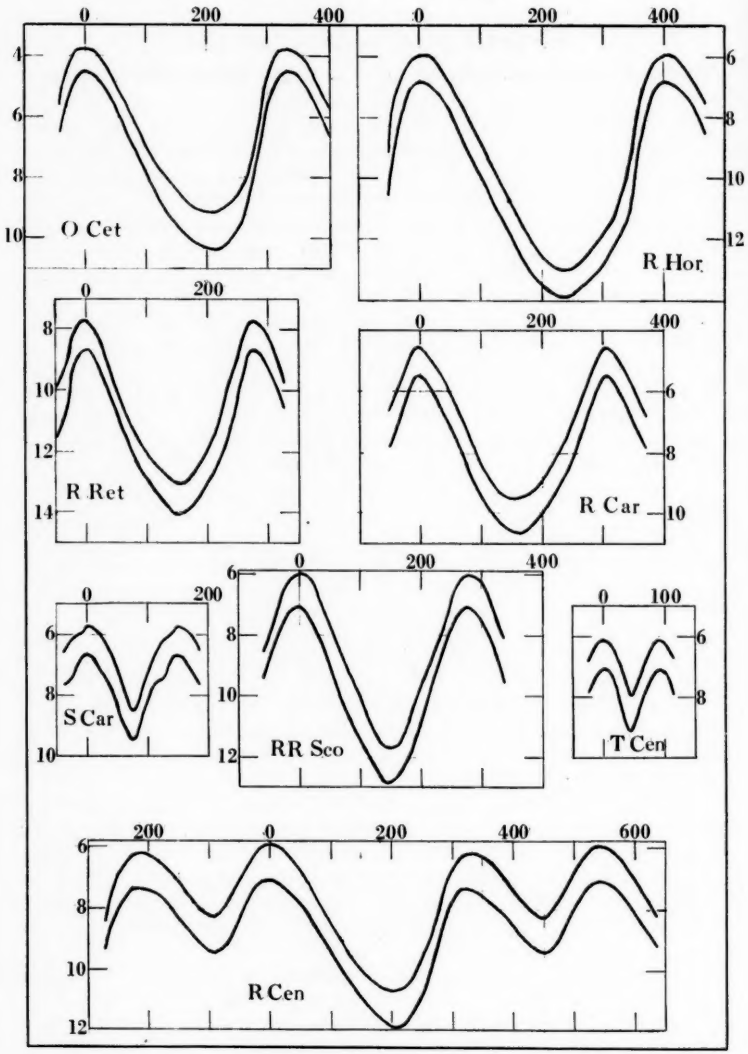
The memoir begins with a special discussion of *Systematic Deviation in Variable Star Observations.* For this discussion eleven well-observed variables were selected as fully observed by fourteen of the contributors. It was concluded that systematic deviation varies with magnitude and does not appear to be connected with the slope of the curve. These deviations remained constant with each observer, and they did not decrease with greater experience, nor were they affected by the use of instruments of different type. The systematic deviations were probably mainly due to the color sensitivity of the individual observer. Accidental errors appeared to be largest when the variable was near maximum brightness, and with inexperienced observers there was a tendency to anticipate changes, especially when the star was due to increase rapidly.

The original observations of the variables discussed have appeared at intervals in the *Circulars* (Nos. 4-22) *of the New Zealand Astronomical Society.* The principal observers were Messrs. G. F. Smith of Dunedin, and F. M. Bateson of Wellington, who contributed 15,827 and 6,941 observations, respectively, out of the total of 35,379 submitted by 35 observers. The observing list included 74 long-period variables, 3 short-period variables, 4 novae, and 9 irregular variables. Published dates of maxima are given for 61 long-periods, and of minima for 22 of the same stars. A comparison of these dates with those derived by the Recorder for 56 of these same stars shows an average difference of $\pm$ 4.8 days for the maxima, and $\pm$ 5.9 days for the minima, a remarkably close agreement for this type of variable. As would be expected, the very red variable, R Leporis, gave the largest difference, while those stars with broad, flat maxima or minima showed the next largest differences.

Mean light curves were derived for nine long-period variables, and the agreement with the curves recently derived by the Recorder for eight of the same stars is also exceedingly close. Although Mr. Bateson does not illustrate his curves, he gives coördinates which permit a comparison with the Harvard-AAVSO curves, which is shown in the accompanying figure, the New Zealand curves being displaced by one magnitude below the corresponding Harvard curves.

There is also included a discussion of two short period variables, β Doradus and l Carinae, with observed dates of maxima and minima, and mean light curves for both. Final elements for β Doradus are: J.D. Max. 2427323.005 E + 9.846 days; M — m, 4.696 days; and mean range, 3.57 to 4.05. For l Carinae the following elements are given: J.D. Max. 2427092.241 E + 35.491 days; M — m, 11.444 days; and mean range, 3.43 to 4.14.

In view of the disruption of observations in general because of the war, it is proposed to abandon the publication of the original observations in the *New*



COMPARISON LIGHT CURVES OF LONG-PERIOD VARIABLES
(Upper: Harvard-A.A.V.S.O.; Lower, New Zealand)

Zealand Circulars and, instead, to submit whatever observations are made to the A.A.V.S.O. for inclusion with their results.

Congratulations are due to the Variable Star Section of the New Zealand Astronomical Society, and to Mr. Bateson in particular, for the presentation of such a fine memoir on these far southern variables. May the members continue to add to their splendid record of achievement, by a long-continued period of activity.

Report on Variable Star Research in the U.S.S.R. A report on the progress of variable star research in the Soviet Union during the past twenty years has just been issued by Captain B. B. Kurkarkin, Secretary of the Commission for Variable Stars, and Professor at the Moscow State University.

Whereas in the earlier years covered by this report special stress was laid on the visual observations of many different types of variables, in the later years the trend has been more to the photographic methods of investigation. Not only were the well-known variables systematically observed, but about 1,000 new variables were discovered and investigated. The observatories which played an active part in this program were those at Tashkent, Stalinabad, Moscow, Pulkovo, and Kasan. In the past five years preceding the start of the second world war, much attention was devoted to the theory and statistics on variables, including their history and bibliography. At Moscow a catalogue of facts concerning all types of variable stars, including suspected variables, is being maintained.

Professor Kurkarkin has contributed much on his own account to the whole problem of variable stars. He states that far more data are required before elaborate investigation can be made, and that such investigation will doubtless lead to the solution of many related problems in stellar astronomy. He also stresses the need for cooperative efforts by observers in other countries.

Despite the curtailment of astronomical work in the Soviet Union during the past few years, an especial effort has been made at the Observatory in Stalinabad to photograph the sky systematically between the north pole and —45° declination with two short-focus astrographic cameras. With the conclusion of the war the Soviet Union will make a still greater attack on the whole problem of variable stars.

The Peculiar Variables: RX Andromedae, 005840; appears to have reached a stage of comparative quiescence again.

SU Tauri, 054319; still faint, below magnitude 13.3.

SS Aurigae, 060547; a maximum indicated near J.D. 2431376, October 12.

U Geminorum, 074922; a maximum near J.D. 2431378, October 14.

Z Camelopardalis, 081473; evidently behaving in a normal manner, with maxima at about twenty-day intervals.

S Apodis, 145971; was still faint as late as August 24, at least not brighter than magnitude 13.5.

R Coronae Borealis, 154428; at normal maximum.

R Scuti, 184205; at minimum, magnitude 7.2 about J.D. 2431380, October 16.

RY Sagittarii, 191033; holding rather steadily at magnitude 8.7, about two magnitudes below normal maximum brightness.

SS Cygni, 213843, a well-observed broad maximum, number 339, near the end of October.

Observations for October: A total of 3,143 observations was contributed by 37 observers, as listed herewith:

Observer	No. Var.	No. Ests.	Observer	No. Var.	No. Ests.
Allen	1	1	Marsh	1	1
Blunck	32	35	Mary	57	87
Boone	35	43	Meek	42	187
Bouton	27	60	Nadeau	105	143
Buckstaff	12	21	Oheim	73	172
Cousins	51	100	Oravec	4	14
Duffie	34	58	Palo	10	10
Fernald	311	709	Parker	43	43
Ford	36	40	Parks	27	48
Garneau	37	43	Peltier	149	212
Guimont	4	4	Reeves	4	4
Hartmann	168	177	Renner	17	17
Holt	53	58	Schoenke	21	25
Howarth	12	12	Sill	42	42
Irland	12	12	Vohman	20	43
Kearons	58	70	Webb	50	55
Kelly	12	16	Webber	100	100
de Kock	67	256	Weitzenhoffer	4	12
Luft	13	213			
			37 (Totals)		3,143

November 13, 1944.

Comet Notes

By G. VAN BIESBROECK

The comet season is getting very quiet. Nothing further has been learned about COMET 1944 *e* (BERRY), the bright object mentioned last month as being discovered in New Zealand. A second rough position, three days after the discovery, was given by the Carter Observatory and confirmed rapid motion toward the sun, but apparently after that the comet was lost in daylight. Very likely it may have been in reach of northern observers for some time, but in the absence of a predicted position there is little chance of locating the object which is probably very faint at present.

As was expected, COMET 1944 *c* (DU TOIT) moving slowly northward in Aquarius has been recorded October 19-22 as a small round coma of magnitude 18. It was located very near the ephemeris position deduced from Bobone's elements (October issue p. 415). It is questionable if it will be possible to trace farther this fading object, but the observations covering now six months establish that the period of 14.87 years is substantially correct.

COMET SCHWASSMANN-WACHMANN I was faint and almost starlike on October 19-22. It should be watched for one more of the expected outbursts of luminosity of this curious object which have occurred so often in the past.

In December COMET 1944 *d* (VAN GENT) will have emerged sufficiently from the vicinity of the sun to become observable in the morning sky. But only large telescopes will be able to reach it.

McDonald Observatory, Fort Davis, Texas, November 14, 1944.

General Notes

Lieutenant Commander Murray Geddes, a distinguished worker and a valued member of the New Zealand Astronomical Society, passed away on July 23, 1944. Mr. Geddes was president of the Society in 1940-41 and at the time of his death he was a member of the Council of the Society.

Portrait of Professor S. A. Mitchell

On armistice day, November 11, a portrait of Professor S. A. Mitchell was presented to the University of Virginia. The simple ceremonies in the Colonnade Club consisted in a brief address by Dr. Walter S. Adams which was read by the Corcoran professor of philosophy, Dr. A. G. A. Balz, who added a personal word of tribute to his friend and colleague. President J. L. Newcomb accepted the portrait for the University. The portrait was unveiled by Dr. Mitchell's grand-daughters aged 13 and 9.

The donor of the portrait was Dr. Beverly C. Smith, a distinguished surgeon of the Columbia University Medical Center in New York. He was a member of the first undergraduate class taught by Dr. Mitchell at the University of Virginia.

Sun-spot Observations Needed

Early in October the Council of the American Association of Variable Star Observers accepted a Resolution and Proposal to organize a group of old and new members for the purpose of making solar observations, particularly of sun-spots.

The need for this project has asserted itself by reason of the fact that because of the war, the Relative Sun-spot Numbers are obtainable only at a very late date from Dr. W. Brunner, Director of the Federal Observatory of Switzerland, the headquarters for solar statistics for the International Astronomical Union.

The importance of the value of sun-spot observations has also asserted itself in that these observations have been and are presently being used by our Government in promoting the war effort.

Report blanks and other material and instructions will be furnished by the committee to those equipped or who can secure the necessary equipment to cooperate in this worthy cause. It is imperative that this be done quickly.

What is presently needed with respect to sun-spots is the total number of groups, whole disc, and the total number of sun-spots, whole disc, daily, weather permitting. There are other factors involved but these depend solely upon the experience of the observer. Full particulars can be had by writing to the undersigned, stating the instruments available. Participation in this program will fill a definite need in science and will be greatly appreciation.

NEAL J. HEINES, *Chairman.*

560 Broadway, Patterson 4, New Jersey.

POPULAR ASTRONOMY

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